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EFFECT OF CLIMATE CHANGE ON PRODUCTION OF DARJEELING TEA: A CASE STUDY IN DARJEELING TEA RESEARCH & DEVELOPMENT CENTRE, TEA BOARD, KURSEONG

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Abstract

A study was conducted at Darjeeling Tea Research and Development Centre (DTR &DC), Kurseong to see the effect of climate change on production of tea. Results demonstrate that productivity of green leaf in 2012 has reduced by 41.97 % and 30.90 % as compared with 1993 and 2002, respectively. Highest productivity of 1974.44 kg green leaf ha^{-1} was obtained during 1994, thereafter productivity was declined continuously. Coefficient of determinants indicated that highest variation of (81.9 %) green leaf yield was due to relative humidity, followed by total annual rainfall (61.4%) and minimum temperature (13.6 %). Stronger positive and significant correlations were found between green leaf yield and relative humidity (r= 0.905) and total rainfall (r=0.78), whereas average maximum temperature showed negative correlation (r=-0.287) with green leaf yield.

Key words: Correlation, Rainfall, Temperature, Relative humidity and Tea.

Background of the Study

Tea is one of the most popular and lowest cost beverages in the world and consumed by a large number of people. Darjeeling tea occupies a place of pride for the whole of India. The aroma and taste of Darjeeling orthodox tea is unparalleled in the world. Tea is grown at an altitude ranging from 600 to 2000 meters above mean sea level and requires a minimum of 50 to 60" of rainfall in a year and for this Darjeeling did not lack. The cool and humid climate, the soil, the rainfall and the slopping terrains all combine to give Darjeeling tea its unique "Muscatel flavour" and "Exquisite Banquet". The combination of natural factors gives Darjeeling tea its unique distinction not found anywhere else in the world. Thus, it is the most sought after and highly valued.

In Darjeeling hills, flushing of the tea crop starts at the end of March when maximum and minimum temperatures exceed 21^{0}C and 14^{0}C respectively (Ghosh Hajra and Kumar, 1999). Thereafter, harvesting of the tea crop continues until September, decline considerably towards the end of October. Low temperature is one of the major climatic variables limiting yield. Low temperature is also the vital factor causing low yields in the cold season in Malawi (Tanton, 1992). The total as well as the distribution of rainfall plays an important role in growth and development of tea. It has been estimated that one hectare standing of mature tea plants requires 10 tonnes of water per day, which is equivalent to 2.5 mm rainfall. In Darjeeling hills total average rainfall is well ahead with the requirement but distribution is a major constraint which is observed in recent past. RH around 80 percent in most of the months is ideal and RH below 40 per cent during dry weather causes damage to the plant and accentuates the drought effect. Being a rain-fed crop grown in different agro-ecological regions, the productivity of tea lands is largely dependent on the environment factors. The total annual rainfall and its distribution, temperature and solar radiation are the most influential environmental factors governing tea yield. Further, environmental factors are responsible for the development of seasonal quality. It is also a known fact that pest and disease incidence is related to the weather pattern. Therefore, temperature rise, increase in ambient CO_2 concentration and extreme rainfall events (heavy rainfall and drought) brought about by climate change (global warming) can affect production and quality of tea. Climate change is set to compound the daunting complex challenges already being faced by agriculture. Global temperatures have already risen by an average of 0.74^{0}C over the last 100 years (IPPC, 2007), and are projected to rise by at least 3 degrees this century, which means a devastation calling for an urgent response. Hingane *et al.* (1985) found that northwest India shows a significant decreasing trend in mean temperature in summer (0.05°C decade^{-1}), confirmed by Kumar *et al.* (1994) for minimum temperature at the same decreasing rate while maximum temperatures have been steady. The lack of information on the effect of climate change on tea under Darjeeling condition, made an impetus to undertake the present study to achieve the objectives furnished below.

Methodology

The study was conducted at the instructional farm of Darjeeling Tea Research and Development Centre (DTRDC), Tea Board, Kurseong. The farm is situated at 26.9^0 N latitude and 89^0 12' E longitudes and at an elevation of 1240 meters above mean sea level. Top soil is about 45 cm deep and sub soil stony, an Umbric Dystrochrept and sandy loam. Mainly inorganic method of cultivation is practiced and bushes are more than 100 years old. Fertilizers were applied @ 120: 45:120 kg NPK ha^{-1} yr^{-1} in the form of urea, super phosphate and muriate of potash. On an average 28-35 plucking round has to be followed in the farm of DTRDC. Out of 18.48 hectares of farm land, approximately 15-20 % vacancy exists. Most of the green leaf yield comes from old chinery bushes and clones namely T-253, Badamtam-15/1, B-157, B-777, MB-6, K-1/1, HV-39, TTV-1, TS-378, RR-17/144, T-135, T-383, AV-2, T-78 and P-312. To accomplish the objective of this study, data on total plantation area (ha), rainfall, temperature, sunshine hour, relative humidity, type of farming, age of bush, plucking round, name of clones/variety, nutrient management and green leaf yield (kg ha^{-1}) of tea for last 20 years were collected from Farm division of Darjeeling Tea Research and Development Centre, Kurseong. Linear correlation analyses were used to determine the association between green leaf, rainfall, temperature and humidity using MS Excel.

Results and Discussion

The data on total annual rainfall & its distribution, mean maximum & minimum temperature, relative humidity, sunshine hour and productivity of green leaf of DTRDC for last 20 years are presented in table 1, 2 and 3. It was observed form these data that the rainy season starts from 1st week of May and continues up to last week of September having intermittent, drizzling and heavy rainfall. The total annual rainfall varies between 226.64 to 558.03 cm, of which 80% fall during May to September**.** The temperature range of this area varies from minimum of 7.91-14.93^{0}C to maximum of 18.10-20.50^{0}C**.** The average relative humidity of the area varies between 76.64 to 92.71 %. The annual mean sunshine hours as recorded varied from 1.59 to 5.71 hours in a day during the period of this study**.** As a result, the area as a whole is humid and cool except having a winter spell during November to February.

Data presented in table 1 depicted that production of tea in terms of green leaf is declining. The reason of reduction in yield may not be solely due to climatic change but there are so many reasons viz. switching over inorganic to organic cultivation practices, age of tea bushes, density of the plants per unit area, rainfall pattern, steep slope, removal of upper layer of fertile soil due to the erosion, depth of the soil etc. may be the major causes behind the gradual declining in production of Darjeeling Tea in general and DTRDC in particular. From the table 1 it is clear that productivity of green leaf of DTRDC in 2012 has reduced 41.97 % and 30.90 % respectively as compared with 1993 and 2002, respectively. Highest productivity of 1974.44 kg green leaf ha^{-1} was obtained during 1994, thereafter productivity was declined continuously. As the farm of Darjeeling Tea Research and Development Centre follow the inorganic method of cultivation so there is no question of yield reduction due to shifting of inorganic to organic cultivation practices. The probable reason may be due to temperature rise, lack of total as well as distribution of rainfall and less humidity, through the influence of these factors on carbohydrate assimilation, respiration, evapo-transpiration, pest and disease infestation, drought and flood incidence and soil degradation. It is observed from table 1 that maximum temperature was rise by 0.51^{0}C over the last 20 years while 152.50 cm of total annual rainfall and 16.07 % relative humidity has decreased, leading to overall production declines.

Simple correlation analysis

Simple correlation analysis revealed that green leaf of tea had highly significant and positive association with total rainfall and humidity (Fig. 1 & 2). Coefficient of determinants indicated that highest variation of (81.9 %) green leaf yield was due to relative humidity, followed by total annual rainfall (61.4%) and minimum temperature (13.6 %). Stronger positive and significant correlations were found between green leaf yield and relative humidity (r= 0.905) and total rainfall (r=0.78), whereas average maximum temperature showed negative correlation (r=-0.287) with green leaf yield.

Conclusion and Recommendation

Considering the socio-economic importance of the tea industry of Darjeeling, it is important to implement adaptation measures in tea plantations, aiming at minimizing adverse impacts of climate without a delay, as it takes a considerable period of time to bring about changes to a tree crop system such as tea cultivation. In this strategy, judicious selection of suitable lands for new planting or replanting, use of drought and heat tolerant cultivars, soil and soil moisture conservation, soil improvement, intercropping, crop diversification, and establishment and management of shade trees are the most viable adaptation measures proposed for tea cultivations.

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Annexure

Table 1: Yearly average minimum and maximum temperature, relative humidity, sunshine hour, total rainfall and productivity of green leaf during the study period

Year	Temperature (^{0}C) Minimum	Temperature (^{0}C) Maximum	Relative Humidity	Sunshine Hour	Total rainfall (cm)	Productivity Green leaf (kg/ha)
1993	13.33	19.99	92.71	3.03	439.25	**1828.47**
1994	13.87	19.69	92.42	3.62	467.87	1974.44
1995	14.88	18.89	91.77	3.61	494.04	1666.42
1996	14.26	18.88	91.17	3.72	425.77	1664.61
1997	14.64	19.24	91.00	3.47	411.81	1658.52
1998	14.53	19.05	90.79	2.96	558.03	1633.57
1999	14.47	19.67	89.92	3.11	400.72	1605.23
2000	12.58	19.31	89.60	2.70	399.71	1598.77
2001	11.02	18.77	89.38	2.95	398.30	1549.83
2002	11.18	18.47	89.21	2.66	387.15	**1535.70**
2003	10.73	18.10	87.96	2.92	382.93	1496.39
2004	11.48	18.27	86.29	2.83	382.31	1387.85
2005	10.73	19.16	85.98	3.17	367.55	1458.41
2006	10.05	19.92	82.72	3.19	367.36	1365.30
2007	8.38	19.20	82.07	1.59	362.16	1357.41
2008	7.91	19.65	82.00	2.06	334.78	1354.67
2009	8.30	19.63	81.18	2.31	326.88	1353.35
2010	11.16	20.05	78.20	2.78	226.64	1326.44
2011	13.93	20.23	83.36	5.12	242.76	1207.68
2012	14.93	20.50	76.64	5.71	286.75	1061.12
Mean	**12.12**	**19.33**	**86.72**	**3.18**	**383.14**	**1504.21**

Table 2: Month wise distribution of rainfall (mm) during the period of study.

Year	January	February	March	April	May	June	July	August	Sept	Oct	Nov	Dec
1993	0.00	0.00	24.60	84.20	266.10	838.00	1130.80	706.60	613.80	175.40	0.00	32.00
1994	60.00	27.40	30.60	19.20	204.60	29.40	677.80	808.60	551.00	19.00	0.00	0.00
1995	10.00	17.80	50.00	28.00	149.50	1379.70	1278.50	823.90	893.20	51.80	240.00	18.00
1996	48.00	11.00	4.00	57.20	178.60	748.60	1007.30	1006.30	610.70	157.60	0.00	0.00
1997	7.20	13.50	89.50	19.60	121.30	369.70	750.00	890.40	748.00	8.20	0.00	251.40
1998	0.00	0.00	246.00	87.50	145.80	641.60	1367.00	1035.30	395.80	26.80	27.20	10.00
1999	0.00	0.00	30.60	60.20	427.10	938.60	1013.10	732.90	569.80	274.60	0.00	0.00
2000	5.00	0.00	15.00	127.60	498.40	995.80	1040.20	877.30	542.60	16.20	0.00	0.00
2001	0.00	0.00	0.00	62.80	194.40	709.80	655.80	235.40	372.60	9.20	12.40	14.00
2002	8.60	11.20	2.40	184.60	594.60	743.40	1240.00	732.30	474.40	0.00	0.00	5.60
2003	0.00	73.60	187.40	204.00	180.40	1340.70	1811.80	602.00	648.80	279.80	0.00	251.80
2004	0.00	0.00	20.80	123.60	288.20	570.20	1268.00	828.40	363.40	129.00	24.00	6.00
2005	105.00	25.20	145.60	269.80	222.00	858.80	1048.80	1211.10	327.60	158.40	4.00	16.20
2006	11.40	0.00	6.20	164.60	435.20	610.00	893.30	248.30	1225.40	38.40	0.00	40.80
2007	1.20	141.20	5.40	51.80	293.20	477.10	1313.30	821.80	808.20	10.40	8.20	75.40
2008	83.20	42.60	176.20	28.60	414.50	634.20	1592.80	1338.60	279.20	58.20	6.60	24.00
2009	8.20	4.20	25.60	256.40	494.00	648.90	1024.50	925.60	394.30	32.20	0.00	9.20
2010	0.00	0.00	0.00	49.10	15.60	1021.20	1280.20	1280.50	536.80	74.30	0.00	0.00
2011	5.20	9.00	17.80	143.50	361.50	785.00	940.50	669.50	684.00	57.50	2.00	0.00
2012	9.50	3.50	2.50	85.50	60.00	489.00	1555.00	478.50	157.50	26.50	0.00	0.00

Table 3: Monthly mean maximum and minimum temperature during the study period.

Year	Maximum temperature (^{0}C)												Minimum temperature (^{0}C)											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
1993	14.1	16.0	18.9	22.3	21.9	23.1	23.3	22.5	22.6	20.6	18.1	16.5	3.1	9.0	11.1	14.1	15.6	18.2	18.4	18.2	16.8	14.7	11.8	9.0
1994	14.9	13.9	19.1	22.0	23.5	22.6	23.2	23.7	22.6	20.0	17.8	13.0	7.6	6.8	11.9	14.3	17.1	18.8	19.1	19.2	18.2	14.2	12.0	7.2
1995	12.8	13.2	18.2	22.7	22.8	21.4	21.2	21.8	21	20.4	17.8	13.4	7.8	9.2	13	16.4	19.5	19.0	18.7	19.4	18.0	15.8	12.8	9.0
1996	11.4	15.5	19.6	22.9	20.6	21.0	20.3	24.5	21.7	18.7	16.5	13.9	7.5	10.2	13.2	15.8	16.1	17.9	18.3	18.4	17.9	15.4	11.7	8.7
1997	13.0	12.5	17.5	23.2	23.5	23.8	24.0	22.1	20.5	20.0	17.3	13.5	8.5	8.9	12.5	15.5	17.3	18.0	20	19.8	18.2	15.5	12.7	8.8
1998	11.8	14.0	15.9	21.2	22.8	21.0	21.5	21.5	22.1	20.8	19.2	16.8	7.1	8.9	10.9	16.0	18.0	19.8	19.2	19.0	18.3	14.7	13.0	9.4
1999	14.3	18.7	20.9	21.6	20.3	22.6	21.2	21.9	20.9	20.1	18.0	15.5	7.3	11.0	13.5	16.2	16.2	18.4	18.3	18.5	17.4	16	11.8	9.0
2000	12.7	13.0	16.0	21.4	22.3	23.5	23.5	23.0	22.5	22.9	18.2	12.7	6.3	6.0	9.0	14.8	15.9	16.6	16.5	17.2	15.9	14.2	11.0	7.6
2001	11.7	11.8	18.6	20.5	19.6	20.6	24.3	25.0	20.4	21.8	18.2	12.8	5.6	8.9	11.6	12.7	13.0	13.3	13.2	13.7	12.8	12.1	9.5	5.8
2002	12.6	13.4	13.5	16.0	19.8	20.4	24.0	23.7	22.9	22.0	18.4	14.9	5.5	5.8	7.7	11	13.8	14.0	15.8	16.5	13.4	12.3	10.3	8.0
2003	11.5	13.0	14.0	17.5	19.8	20.5	21.8	22.9	22.6	21.5	18.4	13.7	5.6	6.2	7.3	10.1	13.8	14.0	14.5	13.6	13.5	12.5	9.8	7.8
2004	11.2	11.6	13.5	20.0	21.0	21.2	23.0	23.2	21.7	22.4	17.9	12.5	5.8	6.0	9.6	12.5	13.8	13.7	14.8	16.8	14.2	13.7	10.4	6.5
2005	12.0	13.4	17.3	21.5	21.9	22.5	22.3	22.3	22.5	21.8	18.5	13.9	5.2	5.6	9.0	11.5	13.5	13.8	13.9	14	14.3	12.8	9.8	5.3
2006	12.0	13.5	15.3	19.1	24.0	23.4	23.1	27.0	24.6	22.2	19.2	15.6	4.8	5.9	7.1	11	14.1	13.5	13.3	14.6	13.4	11.0	7.7	4.2
2007	12.6	13.0	15.5	18.4	21.4	23.4	22.7	23.6	24.1	22.8	19.1	13.8	3.4	3.0	6.8	9.7	11.3	11.3	11.7	11.7	10.9	9.9	7.1	3.8
2008	12.7	13.8	16.2	20.4	24.0	23.9	23.8	24.3	23.3	22.1	17.5	13.8	3.2	4.2	5.9	8.0	10.6	11.0	11.1	10.7	10.6	9.2	6.6	3.8
2009	11.2	14.6	15.6	21.7	23.0	24.7	24.9	23.8	22.8	20.9	20.1	17.3	2.8	4.6	6.2	10.5	11.0	13.0	13.8	11.2	10.0	8.6	5.0	2.9
2010	16.3	16.3	19.7	18.2	20.5	22.8	24.6	23.2	21.9	20.5	17.5	14.0	3.4	3.8	7.4	11.4	12.8	14.5	16.0	15.5	14.6	13.2	11.5	9.8
2011	12.8	16.6	17.5	22.2	22.6	23.7	22.5	23.3	22.9	21.4	18.1	19.1	3.0	5.3	8.2	15.1	17.2	18.8	19.3	18.5	18.5	16.5	12.7	14.0
2012	12.3	16.4	20.6	22.0	25.0	23.4	23.2	24.5	23.0	21.6	18.6	15.2	6.8	10.1	13.4	15.8	18.4	19.5	19.5	19.5	18.7	15.9	12.1	9.4

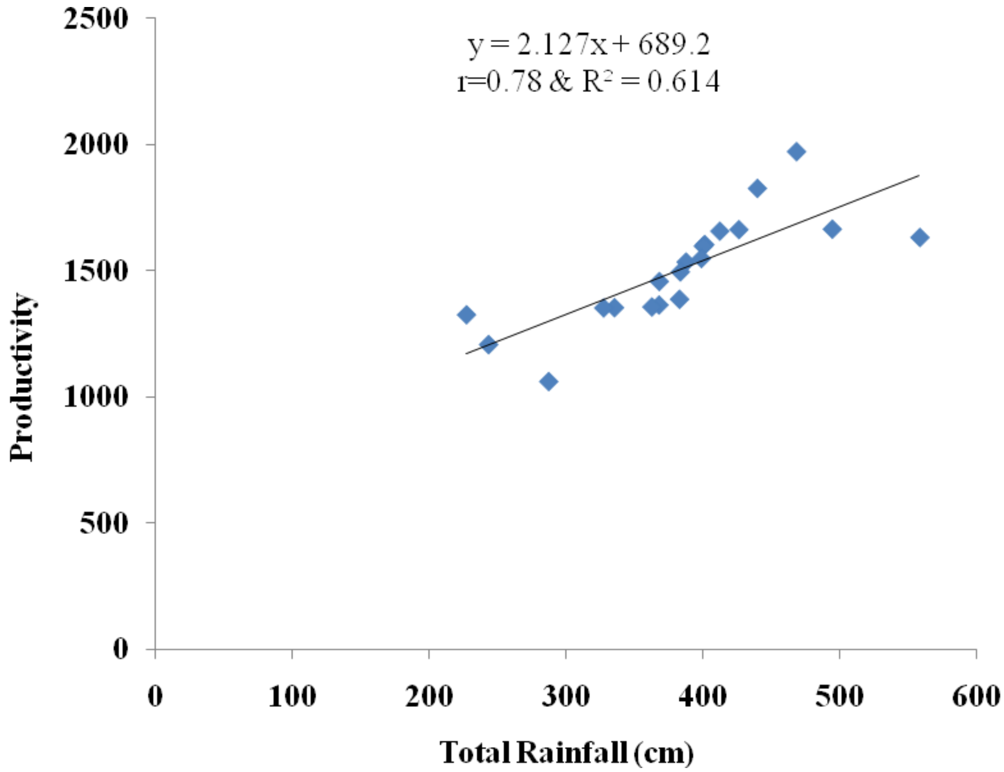

Fig. 1: Correlation coefficient between total rainfall and productivity of tea.

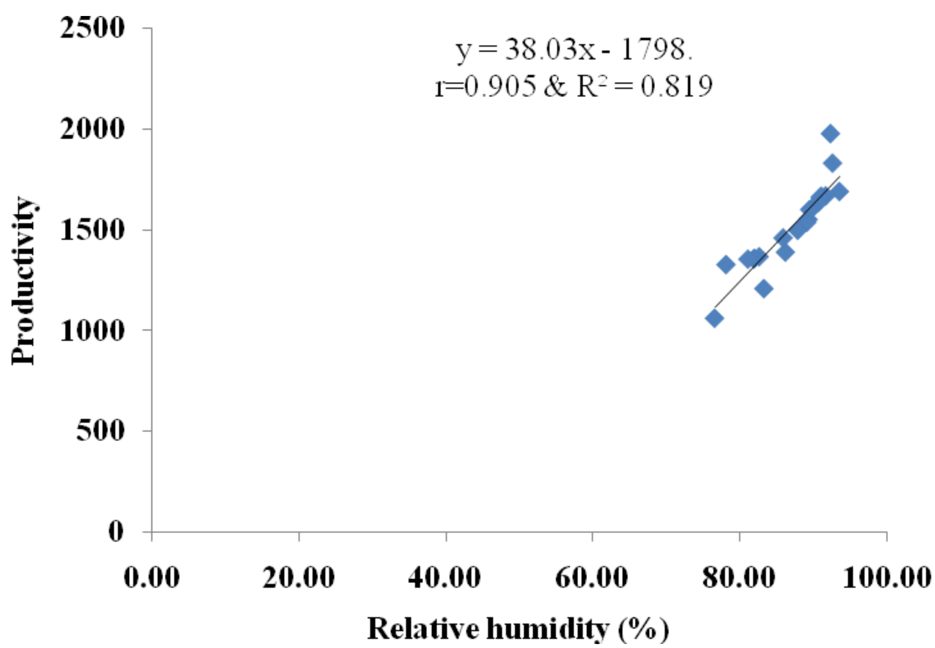

Fig. 2: Correlation coefficient between relative humidity and productivity of tea.

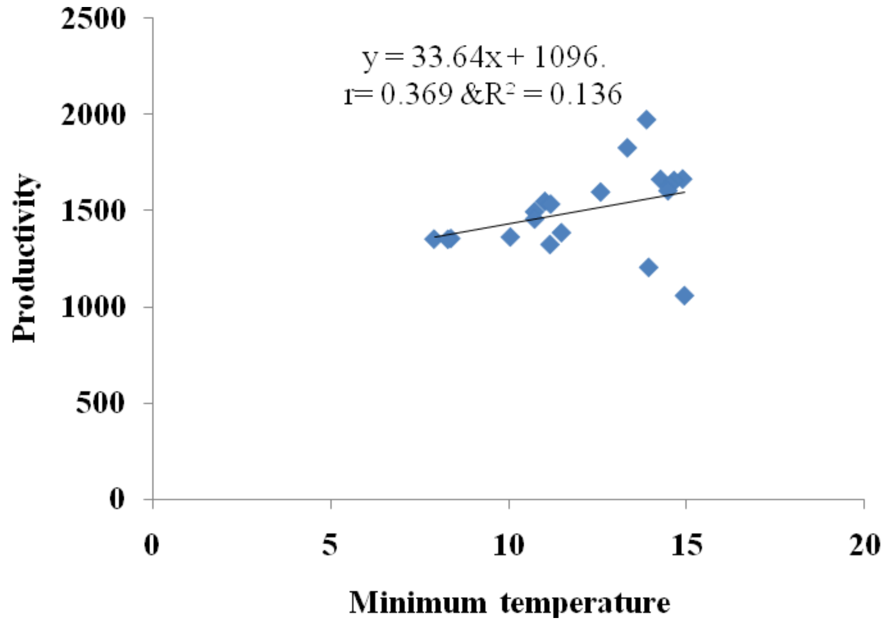

Fig. 3: Correlation coefficient between minimum temperature and productivity of tea.

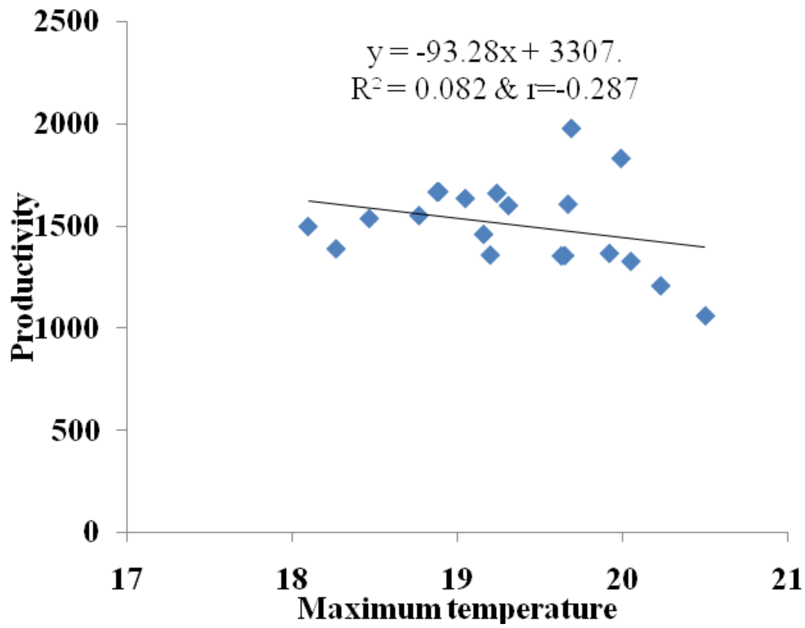

Fig. 4: Correlation coefficient between maximum temperature and productivity of tea.