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Influence of climate on yield of cocoa over Vellanikkara, Thrissur, Kerala

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ABSTRACT

A study was undertaken to study the effect of weather parameters on yield cocoa over Vellanikkara, Thrissur, Kerala. The monthly cocoa yield of the Cadbury – KAU Co-operative Research Project farm were collected for 100 trees from 1991-2007. The weather data for the above period was also collected and pooled according to the cocoa yield data. The mean peak harvest was noticed during May (6.2 pods/tree), followed by March (5.2 pods/tree) while less in February (2.7 pods/tree). The coefficient of variation was very high (48.7 – 124.5 %) in monthly pod yield of cocoa while it was less (23.2 %) in the case of annual yield of cocoa. The mean seasonal pod yield was more during the summer (5.0 pods/tree), followed by Northeast monsoon season (4.1 pods/tree). The results indicated that there was an inverse trend between the annual rainfall and cocoa yield. Wherever the annual rainfall was very high, the annual cocoa yield was low. In the case of temperature, the maximum temperature from January to March had a profound negative influence on annual cocoa yield. From the above it can be inferred that high maximum temperature from January to middle of March together with high rainfall during the rainy season appeared to be detrimental for obtaining better yield in cocoa.

Key words: Climate variability, cocoa, rainfall, temperature, yield variability

The global cocoa production is around 40.85 lakh tones during 2012-13. Ivory Coast leads in cocoa production in the world with a contribution of 33 per cent, followed by Ghana and Indonesia (ICCO, 2014). Unlike in other crops, it appears that the production and demand of cocoa at the global level match each other to a large extent. However, the recent trends I world production of cocoa beans indicated that there were drops in production during 2004-05, 2006-07, 2008-09, 2009-10 and 2011-12 (ICCO, 2012). It was attributed to unfavorable weather conditions in major cocoa producing regions. West Africa, the main cocoa growing regions, was hit by severe harmattan wind (dusty and dry wind from November to March) and its inherent dry weather, which lasted from the end of 2006 to February 2007, had a strong negative impact on global cocoa production. The favorable weather which prevailed over most of the cocoa growing regions during 2010-11 helped to achieve highest production (43 lakh tonnes) in the history. It reveals that the weather abnormalities like floods, droughts, cold and heat waves across the cocoa growing regions of the world adversely the affect the cocoa production and the cocoa industry is likely to suffer. Therefore, there is a need to understand the effect of weather on cocoa yield so as to manipulate the crop for sustenance of yield through better management practices. Hence, a study was undertaken to study the effect of weather parameters on yield cocoa over Vellanikkara, Thrissur, Kerala.

MATERIAL AND METHODS

The present study was undertaken at the Department of Agricultural Meteorology, College of Horticulture, Vellanikkara. The study location falls under the tropical humid climate of B4 – type as per the Thornthwaite (1948) climatic classification. The area is benefitted by both Southwest and Northeast monsoons with an average annual rainfall of 2800 mm. February, March and April are the hottest months with a mean maximum temperature of 35.4ºC. Heavy rainfall from June to September, followed by prolonged dry spell from November is a climatic feature under which cocoa is grown. A strong dry

wind is noticed from 15th November to middle of February due to Palghat gap. It is a special feature in this part of Kerala. The monthly cocoa yield of the Cadbury – KAU Co-operative Research Project farm were collected for 100 trees from 1991-2007. The weather data for the above period was collected from Department of Agricultural Meteorology, College of Horticulture, Vellanikkara and pooled according to the cocoa yield data.

Statistical analysis such as correlation and regression was employed to find out the relationship between weather parameters and cocoa yield. Correlation was introduced by Karl Pearson to study the relationship between two variables. A correlation is a measure of the strength of the linear relationship between two measurable variables. The Pearson correlation coefficient, represented as r, gives the strength and direction of this relationship. The closer r is to 1 or to -1 then the stronger the linear relationship between the two variables. When high values of X are associated with high values of Y, a positive correlation exists. When high values of X are associated with low values of Y, a negative correlation exists. It is important to remember that Pearson's correlation provides information about the direction and strength of the linear relationship between the two variables. In our study cocoa yield data were correlated with weather parameters of 0 to 6 months before pod production.

RESULT AND DISCUSSION

Cocoa yield

The annual pod yield during the study period from 1991-2007 showed a declining trend, indicating that the yield potential of the trees came down year after year due to age of the trees. It was predominant after 2000 onwards **(Table 1)**. The annual number of pods was low during 2004 (28.1 pods/tree), 1998 (40.4 pods/tree), 2002, 2006 (41.0 pods/tree), 2003 (41.6 pods / tree) and 1995 (42.7 pods/tree) while more during 1993 (72.4 pods/tree), 1992 (68.3 pods/tree), 1996 (66.3 pods/tree) and 1999 (59.6 pods/tree). The annual yield was intermediary in 1991 (46.4 pods/tree), 1994 (46.7 pods/tree, 1997 (54.8 pods/tree), 2001 (51.4 pods/tree), 2000 (51.4 pods/tree), 2005 (49.9 pods/tree) and 2007 (49.3 pods/tree).

The mean peak harvest was noticed during May (6.2 pods/tree), followed by March (5.2 pods/tree) while less in February (2.7 pods/tree). The coefficient of variation was very high (48.7 – 124.5 %) in monthly pod yield of cocoa while it was less (23.2 %) in the case of annual yield of cocoa. It indicated that the cocoa monthly yield is very sensitive to weather extreme weather conditions unlike in the case of annual yield.

Table 1. Monthly and annual cocoa yield at CCRP farm, Vellanikkara from 1991-2007

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Annaul
1991	1.9	1.7	1.8	5.5	12.1	11.3	3.7	2.4	1.1	1.1	2.4	1.4	46.4
1992	2	2.8	2.4	7.3	10.6	7.6	12.1	6.9	5.4	4.7	5.8	0.7	68.3
1993	2.5	2.4	2.3	2.5	6.1	15.3	13.8	10.9	7	1.4	3.4	4.8	72.4
1994	3.9	6.7	3.3	2.7	6.6	3.1	4.7	2.2	6.7	6.8	0	0	46.7
1995	1.4	2.9	8.9	1.5	6.5	5.4	0	6.2	0	4.8	0	5.1	42.7
1996	5.1	1.9	5.7	5	5	8	2.5	0	7.1	10.3	6.9	8.8	66.3
1997	7.4	2.4	2.1	1.1	9	2.4	13.9	3.6	4.2	1.3	3.6	3.8	54.8
1998	6	2.4	6	5	6.8	0	1.3	4.6	2.9	0.7	3.1	1.6	40.4
1999	6.8	6.6	3.7	0	8.3	0.8	1.7	3.6	3.9	4.9	14.3	5	59.6
2000	3	4.6	0	4.6	15.1	0	2.6	2.8	2.9	0	8	7.8	51.4
2001	6.4	0	4.3	3.1	3.8	1.1	1.4	4.7	3.6	5.1	5.2	5.8	44.5
2002	8.4	3.3	1.7	4.2	4.7	0.6	0.6	0.6	2.1	4.4	3.9	6.5	41.0
2003	6.2	0.6	4.2	7.2	5.9	0.9	0.9	2.4	5.5	1.1	0.9	5.8	41.6
2004	4	2.4	3	3.3	0	1.32	1	0.1	4.8	3.4	4.8	0	28.1
2005	4.3	2.7	9.7	4.2	4.5	4.3	2.5	0.5	3.2	11.8	1.2	1	49.9
2006	1.8	1.6	8.8	0	0	3.7	0	8.7	4.4	2.1	3.1	6.8	41.0
2007	6.7	1.3	20.5	5.4	0	1.3	1.5	0.2	0.7	5.9	4.3	1.5	49.3
Mean	4.6	2.7	5.2	3.7	6.2	3.9	3.8	3.6	3.9	4.1	4.2	3.9	49.7
SD	2.2	1.8	4.8	2.2	4.1	4.3	4.7	3.2	2.1	3.3	3.4	2.9	11.5
CV (%)	48.7	66.3	92.6	59.9	67.0	110.0	124.5	89.0	55.3	81.0	82.5	73.4	23.2

The cocoa yield is also highly variable during the rainy season (June - August) as the coefficient of variation was very high, varying between 89 and 124.5. It also showed no significant difference between alternate years, indicating that the cocoa is a regular yielder with no biennial bearing tendency (Table 2). The mean seasonal pod yield was more during the summer (5.0 pods/tree), followed by Northeast monsoon season (4.1 pods/tree). It reveals that the pod yield was more during summer, contributing 30.4 per cent to the annual yield (Table 3), followed by Northeast monsoon season (24.6 %). The percentage of pods recorded was low during winter (22.1 %) and Southwest monsoon (22.9 %).

Table 2. Annual cocoa yield in alternate years

Odd years		Even years	
Years	**Yield (pods/tree)**	**Years**	**Yield (pods/tree)**
1991	46.4	1992	68.3
1993	72.4	1994	46.7
1995	42.7	1996	66.3
1997	54.8	1998	40.4
1999	59.6	2000	51.4
2001	44.5	2002	41
2003	41.6	2004	28.12
2005	49.9	2006	41
2007	49.3	-	-
Mean	51.2	**Mean**	47.9
Student t Value = 0.28; not significant			

Correlation between weather and cocoa yield

Results of the simple correlation analysis between weather parameters zero to six months before pod production and number of pods are presented in Table 7. Out of the five weather variables, maximum and minimum temperatures and rainfall had significant relationship with pod production. There was no significant relationship between temperature range, number of rainy days and pod production. Maximum temperature had a positive significant relationship with pod production two months (0.143) prior to pod production. The minimum temperature had both positive and negative significant relationship with the pod production. It had positive relationship during the month (0.154) of pod production and had negative relationship during five months prior (-0.179) to pod production. Rainfall had recorded a negative significant correlation

Table 3. Annual and seasonal pod production of cocoa at CCRP farm, Vellanikkara

Year	Winter	%	Summer	%	SWM	%	NEM	%	Annual
1991	3.6	7.8	19.4	41.8	18.5	39.9	4.9	10.6	46.4
1992	4.8	7.0	20.3	29.7	32.0	46.9	11.2	16.4	68.3
1993	4.9	6.8	10.9	15.1	47.0	64.9	9.6	13.3	72.4
1994	10.6	22.7	12.6	27.0	16.7	35.8	6.8	14.6	46.7
1995	4.3	10.1	16.9	39.6	11.6	27.2	9.9	23.2	42.7
1996	7.0	10.6	15.7	23.7	17.6	26.5	26.0	39.2	66.3
1997	9.8	17.9	12.2	22.3	24.1	44.0	8.7	15.9	54.8
1998	8.4	20.8	17.8	44.1	8.8	21.8	5.4	13.4	40.4
1999	13.4	22.5	12.0	20.1	10.0	16.8	24.2	40.6	59.6
2000	7.6	14.8	19.7	38.3	8.3	16.1	15.8	30.7	51.4
2001	6.4	14.4	11.2	25.2	10.8	24.3	16.1	36.2	44.5
2002	11.7	28.5	10.6	25.9	3.9	9.5	14.8	36.1	41.0
2003	6.8	16.3	17.3	41.6	9.7	23.3	7.8	18.8	41.6
2004	6.4	22.8	6.3	22.4	7.2	25.7	8.2	29.2	28.1
2005	7.0	14.0	18.4	36.9	10.5	21.0	14.0	28.1	49.9
2006	3.4	8.3	8.8	21.5	16.8	41.0	12.0	29.3	41.0
2007	8.0	16.2	25.9	52.5	3.7	7.5	11.7	23.7	49.3
Mean	7.3	15.4	15.1	31.0	15.1	28.9	12.2	24.6	49.7
Seasonal Mean	3.7	22.1	5.0	30.4	3.8	22.9	4.1	24.6	16.5
SD	2.8	-	5.0	-	10.9	-	5.9	-	11.5
CV (%)	38.7		33.4		72.4		48.7		23.2

Table 4. Cocoa yield (pods/tree) during southwest and northeast monsoon season in good and bad yield years

Months	Pod yield in good years	% increase in yield	Pod yield in bad years	% reduction in yield
June	7.9	51	1.6	59
July	7.5	49	0.9	76
August	5.4	33	2.5	31
September	5.9	34	2.7	31
October	5.3	20	2.8	37
November	7.6	80	2.6	38
Mean	6.6	45	2.2	45

with the pod production two months (-0.140) prior to pod production.

It shows that rainfall had negative correlation with annual yield while positive correlation with the maximum temperature two weeks prior to pod production. Interestingly, rainfall had negative correlation throughout the pod development period (0-6 months), initiated from pod set to harvest. It is evident that high rainfall in the humid tropics may not be conducive for obtaining better yield in cocoa. High rainfall may result in water logging, less bright sunshine, heavy cloudiness and high relative humidity. These factors may in turn lead to immature fruit drop during its developmental phase and heavy disease incidence in cocoa like pod rot. The incidence of pod rot may damage the crop to a considerable extent. It might be one of the reasons for high variation in monthly cocoa yield. It indicated that the weather variables such as heavy rainfall during rainy period and high maximum temperature during summer had direct and indirect adverse bearing impact on cocoa yield.

Climate and cocoa yield:

There was an inverse trend between the annual rainfall and cocoa yield (Fig 1.). Wherever the annual rainfall was very high, the annual cocoa yield was low.

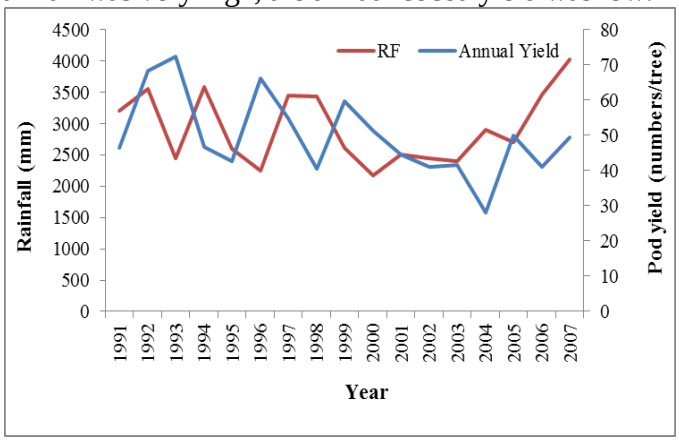

Fig 1. Annual rainfall and cocoa yield from 1991-2007 at Vellanikkara

For example, the annual rainfall recorded was high (3579 mm) in 1994 against the normal (2803 mm) and the yield during the year was low (46.7 pods/year). Similar trend was also noticed during1998 (40.4 pods/tree), 2004 (28.1 pods/tree) and 2006 (41.1 pods/tree) during which annual rainfall was 3435 mm, 2895 mm and 3460 mm, respectively. Whereas in 1993, 1996, 1999 and 2000, the annual rainfall recorded was relatively less (2439 mm, 2241 mm, 2619 mm and 2173 mm, respectively) against the normal and the annual cocoa yield during the above years was 72.4 pods/tree, 66.3 pods/tree, 59.6 pods/tree and 51.4 pods/tree, respectively. It revealed that the annual cocoa yield was relatively low when the annual rainfall was high against the normal rainfall and *vice-versa*.

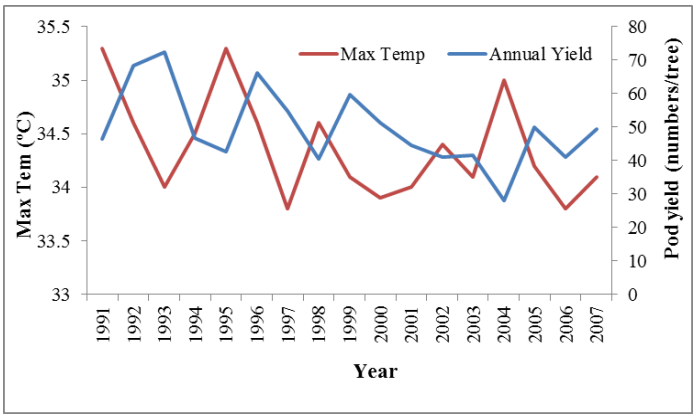

Fig 2. Maximum temperature from January to March and annual pod yield of cocoa from 1991-2007 at Vellanikkara

In the case of temperature, the maximum temperature from January to March had a profound influence on annual cocoa yield (Fig 2.). Whenever there was an increase in maximum temperature, the annual cocoa yield recorded was low. For example, the maximum temperature recorded between January and March was high (35.3 ºC) in 1995 against the normal (34.6 ºC) and the annual cocoa yield was low (42.7 pods/tree). It was also true during 2004 (35.0 ºC) in which low yield (28.1 pods/tree) was obtained. Whereas, the maximum temperature recorded in 1993 was low

(34.0 ºC) and the annual cocoa yield was high (72.4 pods/tree). Similar was the case in 1997 and 2000 as the annual cocoa yield recorded during the above years were 54.8 pods/tree and 51.4 pods/tree, respectively.

On examination of good and bad yield years, it was found that the difference in cocoa yield during southwest monsoon months was very significant followed by northeast monsoon season against the normal when compared to that of other seasons. On an average, the decline in yield was 45 per cent in bad yield years when compared to the mean yield while 45 per cent increase in good yield years during the southwest monsoon and northeast monsoon when compared to that of normal (Table 4).

The percentage increase in yield during good years when compared to that of bad years was 72 and 58 per cent during southwest, northeast monsoon, respectively. Interestingly, there was no yield difference between good and bad yield years during while increase in summer was only 13 per cent (Table 5). The maximum temperature during summer was high (34.7 ºC) in poor yield years while less (34.2 ºC) in good yield years. A mean maximum difference of 1.1 ºC was noticed in April between good and poor yield years (Table 6). It revealed that high maximum temperature during summer with heavy rainfall during rainy season is likely to affect the annual cocoa yield adversely.

The daily maximum temperature during the period from January to May, daily rainfall from December to May and rainfall in the monsoon season during the low and high yielding years were critically analysed to find out the possible explanation in variation of pod yield of cocoa. The maximum temperature during summer showed that there was a sharp rise (1-3 ºC) in maximum temperature during the period from 14th January to 16th March in 2004 (Worst drought year) as against the normal maximum temperature of 33.0 to 36.5 ºC. The drought during summer led to a severe water deficit which was present till May. In addition, lack of summer showers during February and March worsened the situation and led to early severe drought, which was identical to late summer drought of 1982-83. It adversely affected the plantation crops' production. The yield loss was more than 30 per cent in cardamom tracts of Idukki district due to severe water stress coupled with adverse weather during the period. Similar trend was also noticed in the case of cocoa, as the reduction of pod yield was to the tune of 43 per cent in 2004. A decline of 39 per cent in annual cocoa yield was noticed when large field sample size was considered within the same farm.

Table 6. Monthly maximum temperature during summer in good and bad yield years

Months	Max. temp in good yield years (ºC)					Min. temp in bad yield years (ºC)				Normal (ºC)
	1992	1993	1996	1999	Mean	2004	1998	1995	Mean	
January	32.6	32.7	33.1	32.4	32.7	33.4	33.1	32.9	33.1	32.8
February	34.4	34.1	34.7	34.5	34.4	35.2	34.4	35.4	35.0	34.8
March	36.9	35.4	36.4	35.5	36.1	36.5	36.2	37.6	36.8	36.1
April	36.3	35.6	34.6	33.4	34.9	34.8	36.5	36.6	36.0	35.4
May	33.8	34.4	32.8	30.7	33.0	30.4	34.2	33.5	32.7	33.8
Mean	34.8	34.4	34.3	33.3	34.2	34.1	34.9	35.2	34.7	34.5

Table 7. Relationship between weather variables of 0 to 6 months before pod production and pod production

Months	Max.temp	Min.temp	Temperature range	Rainfall	Rainy days
0	0.095	0.154*	0.037	-0.041	-0.049
1	-0.025	0.113	-0.058	-0.038	-0.083
2	0.143*	-0.069	0.126	-0.140*	-0.126
3	0.141	-0.084	0.080	-0.052	-0.078
4	-0.020	-0.109	0.025	-0.063	-0.072
5	-0.076	-0.179*	-0.006	-0.048	-0.022
6	-0.047	-0.070	-0.021	-0.027	-0.011

**Correlation significant at 0.01 level; *Correlation significant at 0.05 level

Similarly the maximum temperature was high in all the low yield years like 1995, 1998, 2002 an 2003 when compared to that of average annual yield. The yield reduction during the above years against mean pod yield was 14, 19, 18 and 16 per cent, respectively. The annual maximum temperature was the highest (33.0 ºC) during 1995 and it was always high against the normal during summer months except in May in which the cocoa yield

was low as mentioned above. Though the annual maximum temperature was 33.0 ºC, the summer temperature went up to 37.6 ºC during March. Murray and Spurling (1964) reported that the apical dominance was lost when cocoa is constantly exposed to high temperature. In the good yield years like 1993, the maximum temperature from January to March was below normal (1-4 ºC) and the yield obtained was 33 per cent more than the normal.

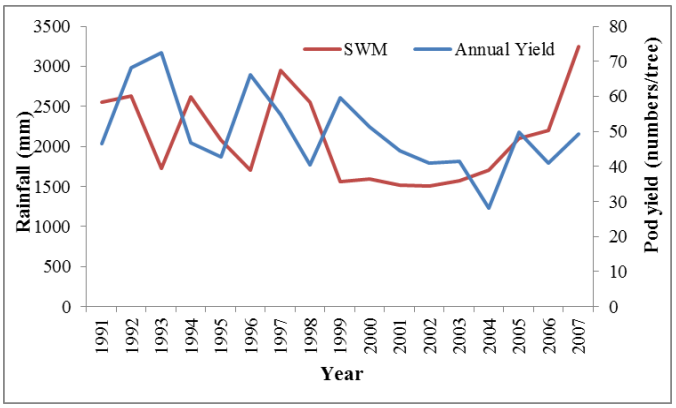

Fig 3. Rainfall during Southwest monsoon and cocoa pod yield from 1991-2007 at Vellanikkara

High yield during 1993, 1996 and 1999 could be explained due to low maximum temperature during summer followed by relatively less rainfall during monsoon. Similar trend was also noticed to some extent in 1992 in which high yield was recorded. However, the maximum temperature recorded in March and April during 1992 was relatively high while less in January and February against the normal. Interestingly, abnormal wet spells were not noticed during the peak rainy season from June to September and rainfall recorded was low with intermittent dry spells against normal (2122.2 mm) in all the good yield years except in 1992 during which the monsoon rainfall was relatively high (2721.3 mm). Prameela (1997) also reported that heavy rainfall was detrimental to the cocoa pod production. It appears that the maximum temperature from January to March had profound negative influence on cocoa yield during the following months from June to August in addition to high rainfall recorded during rainy season (Fig 3.). Probably, it might be the only factor which influenced significantly the monthly yield during the rainy season as the yield difference mainly noticed during the rainy season only between the good and bad yield years (Fig 4.). According to Alvim (1981), yield variability from year to year was more affected by rainfall distribution than any other climate factor.

On further examination through stepwise regression, it was understood that the model explained 43 per cent variation in pod yield of cocoa due to maximum temperature. The equation for the yield prediction is as follows;

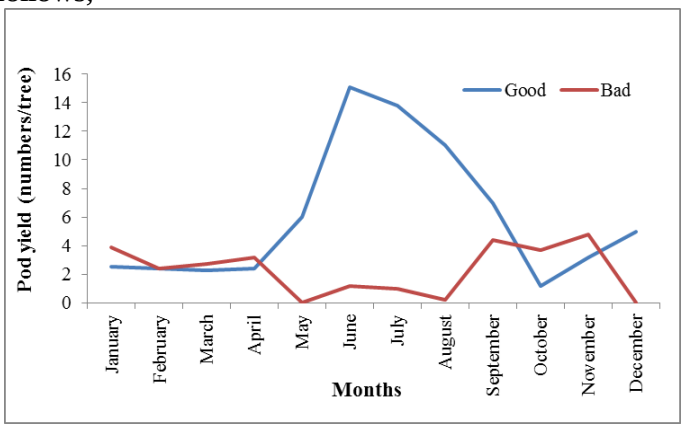

Fig 4. Cocoa pod yield from January to December of a good and bad yield years

$Y = -24.453 + (0.378 \text{ max1}) + (0.516 \text{ Max } 2)$; ($R^2 = 0.43$)

Y – Yield; Max 1 & Max 2 – Maximum temperature one and two months before pod production.

From the above it can be inferred that high maximum temperature from January to middle of March together with high rainfall during the rainy season appeared to be detrimental for obtaining better yield in cocoa. Probably it is one of the reasons why, the cocoa productivity is low across the state of Kerala as the cocoa plantations are exposed to heavy rainfall from June to September and high summer maximum temperature in addition to poor soil moisture under rainfed conditions.

CONCLUSION

The study revealed that the high maximum temperature from January to middle of March together with high rainfall during the rainy season appeared to be detrimental for obtaining better yield in cocoa.

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