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Short Communication

Genotypic and seasonal variations affecting yield attributes of cocoa (*Theobroma cacao* L.) varieties

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Cocoa (*Theobroma cacao*), the chocolate tree, is a perennial crop originated in the amazon basins of South America. Chocolate is one among the very few delicacies which is equally loved by every nook and corner of the world. South India is considered as the best place in India to cultivate cocoa on a large scale (Jayasekhar and Ndung'u, 2018). Climate is an important factor which determines the productivity of a crop (Nix, 1976). Preliminary studies conducted in Kerala Agricultural University indicated that flowering and fruiting pattern of cocoa are influenced by the complexity of environmental factors (Manikandan, 2009; Rao and Gopakumar, 2016). Sujatha *et al*. (2018) compared the impact of climate change and weather variability on arecanut and cocoa in humid tropics of India and reported that cocoa was more affected by climate variability than arecanut. For the growth and development of cocoa the most suitable climatic requirements are a maximum and minimum temperature of 32^{0}C and 18-20^{0}C respectively, relative humidity between 70-80 per cent and total rainfall in the range of 1500-3000 mm (Wood, 1985; Prasanna kumari *et al*., 2009). Change in weather pattern could have a significant impact on seasonal life cycle of cocoa and this effects timing of flower and fruit production and ultimately influence the market price. Increase in summer temperature of about 2-3^{0}C had resulted in a decline of 39 percent of annual cocoa yield during 2004 (Nybe and Rao, 2005).

The experiment was conducted at the research farm of Cocoa Research Centre, Kerala Agricultural University. The KAU released varieties included for the study are CCRP 1, CCRP 2, CCRP 3, CCRP 4, CCRP 5, CCRP 6, CCRP 7, CCRP 8, CCRP 9 and CCRP10. Five plants per variety were observed for their flowering and fruiting pattern during three consecutive years. To study the influence of season the whole year was divided into three seasons *viz*., summer (Febraury - May), monsoon (June - September) and post monsoon (October - January). Observations were recorded on number of flowers produced and yield (number of mature pods per tree per year). The field observations were tabulated and pooled to get mean value of the characters for the respective season.

The daily meteorological data was recorded in the agrometeorological observatory situated in the close vicinity of cocoa farm. Weather variables considered were maximum temperature (^{0}C), minimum temperature (^{0}C), relative humidity morning (%), relative humidity evening (%), rainfall (mm), number of rainy days and mean sunshine hours. To quantify the influence of weather parameters on yield correlation analysis was carried out using Pearson correlation coefficient method in IBM SPSS software. Linear regression analysis was also done to establish relationship between the yield and with the weather parameters. Also, based on the regression analysis prediction model in the form of regression equation was developed.

Influence of seasons on flower production and yield

Growth cycle of perennials are influenced by several factors like temperature, day length, amount of water, wind etc. In a particular season a perennial crop invests more energy on some of the important development stages and it varies with crop species. In the present study we analysed the effect of seasons on number of flowers produced, and yield (number of mature pods per tree per year) in KAU released cocoa varieties and the result is depicted in Fig. 1 and 2. Results showed that both the characters exhibited seasonal variation in its degree of expression. Between varieties also there was slight variation in peak season for the characters.

According to Omlaja *et al*., (2009) flower production in cocoa is influenced by climatic factors. In the present study, number of flowers produced per plant was maximum during monsoon in CCRP 1, CCRP 4, CCRP 7, CCRP 8, CCRP 9 and CCRP 10 and in rest of the varieties flower production was in peak during post monsoon season.These results are in accordance with Omolaja *et al*., (2009) that flowering intensity in cocoa is promoted by rainfall. Number of flowers produced was very low in summer and it is about

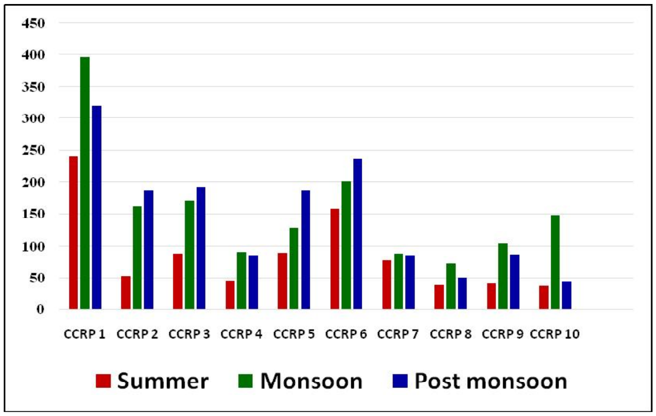

Fig. 1: Seasonal influence of flowers / plant during three seasons

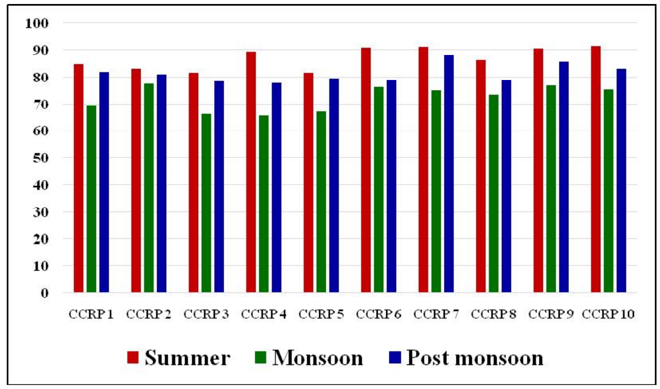

Fig. 2: Seasonal influence of yield (no. of mature pods/tree/ year) during three season

half less than that of other seasons. According to Alvim (1966) and Asomaning *et al*., (1971) flowering in cocoa is mainly affected by temperature and rainfall, flower production may completely inhibit if the condition is extreme dry or cold. The unfavourable weather condition prevailing in summer season may be the reason for reduction in number of flowers produced.Yield was maximum during summer irrespective of variety. Favourable climatic condition prevailing in monsoon and post monsoon season results in enhancement of pod yield in summer. Monsoon season exhibited least number of mature pods. Due to the adverse climatic conditions; flowering, pollen fertility and stigma receptivity will be less during summer which indirectly results in reduction of mature pods in monsoon. Even though high variability was observed for flower production among varieties there was no much variation in yield. The reason for this can be attributed to the fact that cocoa is a crop that cannot accommodate fruits more than its genetic potential. Hence, even if a genotype produce large number of flowers, they will be lost due to natural mechanism called cherelle wilt (Mckelvie, 1956). Since all the genotypes considered under the study are superior genotypes released from KAU, their yield potential is also comparable. Hence much variability is not observed in the number of mature pods harvested.

Relationship between weather variables and yield

Pearson's correlation coefficient was used to find out the relationship of flowering and fruiting with weather parameters and the results are summarised in Table 1. When correlation between yield and weather parameters were considered, all the varieties showed negative correlation with RH morning, RH evening and rainy days. Similar trend was noticed when seasonal influence of yield was considered, among the three seasons monsoon has the lowest yield. Accordingly, yield will be more if relative humidity and number of rainy days is less. This finding is consistent with that of Ojo and Sadiq (2010), they reported that increase in rainfall results in decrease in yield. Mean sunshine hours showed a positive correlation with yield. This indicates that, even though cocoa is a shade loving crop it requires certain amount of sunlight to give a better yield. Sujatha *et al*. (2018) also reported similar findings, theyevaluated the performance of cocoa planted as intercrop in arecanut plantation and suggested that sunshine hours has positive impact on cocoa yield. CCRP 8, 9 and 10 showed high significant positive correlation with maximum temperature for yield which shows its suitability for cultivation in tropical conditions. When correlation between cocoa yield and temperature is considered scientists have two views. Nkobe *et al*. (2013) reported that temperature has a weak positive correlation with yield. Nyasse (1997) stated that increased temperature provides favourable environment for breeding of insect pests and this has proven to have negative effect on cocoa yields as the insects destroy the cocoa pods. However, Oluyole *et al*. (2013) observed that temperature has positive significant effects on cocoa yields.

Weather is always an important reason of uncertainty in agriculture. In the present study we explored the use of weather parameters in developing prediction model which can forecast yield. Since number of mature pods per tree is the important economic characters, they were considered for developing yield forecasting model (Table 2). We have attempted to develop yield prediction models for all the varieties however, in some of the varieties only less than 50 per cent of yield can be predicted using these regression equations. When prediction model for number of pods per

Table 1: Correlation of weather parameters with no. of pods/tree/year (Yield)

Varieties	Maximum temperature (^{0}C)	Minimum temperature (^{0}C)	RH morning (%)	RH evening (%)	Rainfall (mm)	Rainy days	Mean sunshine hours
CCRP 1	0.343*	-0.351*	-0.891**	-0.627**	-0.693**	-0.624**	0.662**
CCRP 2	0.108	-0.487**	-0.657**	-0.431**	-0.457**	-0.408**	0.488**
CCRP 3	0.100	-0.355*	-0.871**	-0.425**	-0.502**	-0.424**	0.463**
CCRP 4	0.185	-0.344*	-0.636**	-0.481**	-0.493**	-0.458**	0.507**
CCRP 5	0.047	-0.486**	-0.568**	-0.397**	-0.411**	-0.376*	0.430**
CCRP 6	0.035	-0.482**	-0.489**	-0.314*	-0.325*	-0.285	0.351*
CCRP 7	0.138	-0.100	-0.582**	-0.420**	-0.517**	-0.433**	0.429**
CCRP 8	0.581**	-0.357	-0.845**	-0.659**	-0.840**	-0.580**	0.674**
CCRP 9	0.572**	0.531**	-0.738**	-0.683**	-0.734**	-0.738**	0.639**
CCRP10	0.645**	-0.570**	-0.652**	-0.573**	-0.682**	-0.662**	0.618**

* indicates significance at 5% and ** indicates significance at 1%

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Table 2: Regression model for Yield

Varieties	Regression models	R^2
CCRP 1	-39.783 + 2.251 * Min. Temp. (21st week) + 0.234 * Max. Temp. (21st week)	0.48
CCRP 2	106.293 + -3.527 * Max. Temp. (9th week) + 1.504 * Min. Temp. (6th week) + -0.983 * Rain fall (11th week).	0.84
CCRP 3	19.660 + -3.800 * Rainy days (4th week)	0.21
CCRP 4	23.553 + -0.113 * RH_1 (14th week) + 0.1 * Max. Temp. (9th week)	0.57
CCRP 5	37.274 + -0.215 * RH_1(19th week)	0.43
CCRP 6	28.022 + -0.499 * Min. Temp (4th week)	0.24
CCRP 7	64.081 + -0.278 * RH_1(9th week) + 0.195 * Max. Temp. (1st week) + -1.171 * Min. Temp. (10th week)	0.61
CCRP 8	7.089 + 0.421 * Max. Temp. (9th week)	0.42
CCRP 9	39.397 + -0.631 * Max. Temp. (16th week) + 0.218 * Rainfall (9th week) + 0.124 * RH_1 (2nd week)	0.61
CCRP 10	15.803 + -0.135 * Max. Temp. (16th week) + 0.222 * Max. temp. (9th week) + 0.195 * RH_2 (6th week)	0.67

tree was considered the coefficient of determination was more than 0.6 for CCRP 2, CCRP 7, CCRP 9 and CCRP 10. Thus, it indicated that for these varieties yield up to 60 per cent can predicted by using this equation.

From the result it can be concluded that temperature, relative humidity and rainfall are the important weather parameters that influence the cocoa yield. Thus, these regression models can provide yield forecast in lead time and this empower the farmers and policy makers to make strategic decision.

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