Research Article
doi: 10.25081/jpc.2019.v47.i3.6053
Journal of Plantation Crops, 2019, 47(3): 173-179

Seasonal variation in yield and yield contributing characters of selected cocoa clones

J. S. Minimol *, T. K. Shija, B. Suma, P. G. Chithira and K. S. Shilpa

Cocoa Research Centre, Kerala Agricultural University, Thrissur 680656, Kerala, India

(Manuscript Received: 12-12-2018, Revised: 11-11-2019, Accepted: 18-11-2019)

Abstract

Cocoa, the only source of chocolate, is divided into three groups *viz.* Forastero, Criollo and Trinitario. This study was taken up to gauge the performance of 12 years old cocoa clones of three types. Among these, Forastero was found to perform well under tropical conditions in all three seasons. The performance of Forastero was unrivaled with pod weight 429.95 g and wet bean weight 117.79 g. All three varieties performed well under post-monsoon season exploiting advantages of monsoon. When correlated with weather, it was observed that number of rainy days, rainfall and relative humidity had a negative correlation with number of pods, whereas mean sunshine hours had a positive correlation with pod weight, wet bean weight, and TSS. In order to comprehend the significance of weather parameters, canonical correlation was estimated. The high value indicated that all the weather parameters influenced the characters to a great extent. Rainfall, temperature and relative humidity were the three climatic factors influencing the yield parameters. High R^2 value obtained in prediction model suggested that it could be efficiently used in the prediction of yield and yield contributing characters of cocoa.

Keywords: Criollo, Forastero, prediction model, seasonal influence, *Theobroma cacao*, Trinitario

Introduction

Cocoa (*Theobroma cacao* L.), popularly known as 'Food of Gods', is the only source for chocolate. The substitution of chocolate flavour by artificial means is inconceivable, which adds to the fascination of the crop. The three main varieties of cocoa plants are Forastero, Criollo, and Trinitario (Cheeseman, 1944). Forastero is widely cultivated type in the world (about 90 per cent) and utilized for bulk chocolate production (Trognitz *et al*., 2011). Criollo is considered as 'Fine flavor chocolate'.

Principal nations where Criollo cultivation can be seen include Mexico, Guatemala, Colombia, Venezuela, Madagascar, Nicaragua, Sri Lanka, Indonesia, and Samoa islands. Criollo cocoa possessed an exceptionally reddish colour, profoundly wrinkled, warty in appearance, with a very thin pod wall. Seeds are extensive in size, plumpy and almost round and cotyledons white or pale violet. They are highly susceptible to extreme climate and pest and disease attack (Almeida and Valle, 2007). However, quality-wise they are graded as high. Beans ferment rapidly and have strong aroma and low astringency (Prasannakumari *et al*., 2018). Global cultivation this variety will account only five per cent.

Trinitario is a natural combination of Criollo and Forastero (Yang *et al*., 2013), which will manifest the character of both. There are genotypes that demonstrate the typical character of Criollo or Forastero. However, it is possible to isolate some natural Trinitarios which have the hardiness of Forastero and quality of Criollo or to breed man-made Trinitario with the above quality (Ajmal, 2016). They can add to the production of 'fine chocolate' in non-traditional area for Criollo cultivation.

Forastero is a common group that adds to larger parts of universal cocoa production. These groups indicate wide variability. Typical Forastero pods are green during unripe condition and turn yellow on ripening. Pods have thick walls and seeds are profoundly pigmented with dark violet colour (Prasannakumari *et al*., 2009).

**Corresponding Author: minimoljs@gmail.com*

Cocoa in spite of the group difference is an ever flowering and fruiting plant, with certain peaks in certain periods of the year. Flower production, fruit set, fruit development differs with the season and thus yield of cocoa is subject to weather to a huge extent (Manikandan, 2009). In this study, an endeavor was made to judge how different seasons influence pod set and pod characters of various cocoa types.

Materials and methods

The experiment was carried out at the Cocoa Research Centre, Kerala Agricultural University, Vellanikkara, Thrissur, Kerala. Five clonal plants each from following genotypes were selected for the study.

Typical Criollo: T 48/1716

Typical Trinitario: ICS 95 and SC 20

Typical Forastero: SCA 6 and IMC 67

The 12-year-old plants of these clones were maintained in cocoa field with a 50 per cent shade level. Recommended Kerala Agricultural University (KAU) package of practices were adopted for their management.

These plants were observed at monthly intervals. Information was recorded on total number of pods harvested per month per tree to assess the yield. Yield contributing characters like pod weight (g), number of beans per pod, wet bean weight (g) per pod and TSS (%) were recorded for five pods every month. The experiment was continued for three sequential years and the data were pooled and average was taken. In order to understand the seasonal influence, the whole year was divided into three seasons *viz.* summer (Feb-May), monsoon (June-Sept.) and post-monsoon (Oct-Jan). The data observed were pooled according to the season and were correlated with the weather.

The weather parameters studied include maximum and minimum temperature (^{o}C), morning and evening relative humidity (%), rainfall (mm), number of rainy days and mean sunshine hours. In order to understand the effect of the selected weather parameters, on pod characters of Criollo, Trinitario, and Forastero, canonical correlation was carried out.

Regression analysis was carried out in order to arrive at the prediction formula for important characters using SPSS software.

Results and discussion

The pooled data on the performance of Forastero, Trinitario, and Criollo, are exhibited in Table 1. The performance of Forastero was unrivaled with pod weight of 429.95 g and wet bean weight of 117.79g. The study was in tune with earlier works affirming that Forastero performs well under tropical climatic conditions (Wood and Lass, 1985; Efombagn, *et al*., 2009; Aikpokpodion, 2012).

The data on the influence of three different seasons on the number of pods per tree, pod weight (g), number of beans, wet bean weight (g), TSS (%) and fat (%) are delineated in Figures 1-6. Forastero demonstrated consistent superiority over Trinitario and Criollo in all the three seasons. This showed its hardiness and superiority in genetic potential when compared with the other two types (Wood and Lass, 1985).

Table 1. Performance analysis of Forastero, Trinitario and Criollo cocoa

Cocoa types	Pod wt. (g)	Pod length (cm)	Pod breadth (cm)	Husk thickness (cm)	No. of beans	No. of flat beans	Wet bean wt. (g)	Yield (No. of pods tree^{-1} year^{-1})
Forastero	429.95	16.27	7.75	1.04	41.17	0.46	117.79	32.68
Trinitario	392.33	16.37	7.19	1.04	39.02	0.61	88.67	26.35
Criollo	349.95	14.42	6.56	0.71	32.46	0.45	72.28	18.86
CV (%)	11.67	4.36	5.07	29.98	5.89	57.98	11.94	7.58
CD (0.05 %)	29.98	0.51	0.27	0.21	1.67	NS	8.29	2.66

When individual characters like the number of pods per tree per year, pod weight and wet bean weight were considered, regardless of the types the values were higher during post-monsoon period. This is the reflection of monsoon season with cool climate and plenty of water. Pods formed during monsoon will become mature during post-monsoon season. Therefore, the favourable climatic condition prevailing during monsoon season was profited for the pod development and thus resulted in enhancement of all yield contributing characters during the post-monsoon period (Egbe and Owolabi, 1972; Minimol *et al*., 2015). Total bean number and TSS were higher during summer. However, the number of beans is not considered as alluring character since it will intern result in reduction of bean size (Prasannakumari *et al*., 2005; Rubeena, 2015). When compared to Forastero, Trinitario types are much influenced by the environment delivering more beans during summer. Less amount of water in pulp content will bring about increment in TSS during summer. It was observed that Criollo types are with more TSS content compared to other two types. The high amount of sugar in pulp is one motivation to draw in more microorganisms towards it and effect good fermentation resulting in the quality cocoa. As reported by Prameela (1997), all characters were inferior during monsoon due to adverse climatic conditions and shortage of water experienced during summer season.

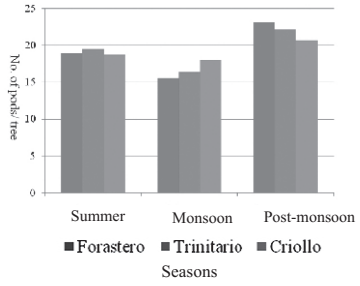

Fig. 1. Seasonal influence of no. of pods per tree during three seasons

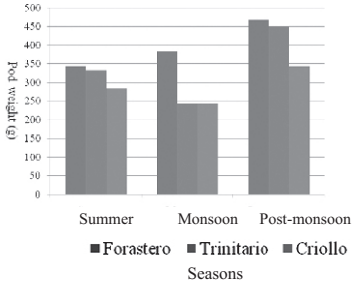

Fig. 2. Seasonal influence of pod weight during three seasons

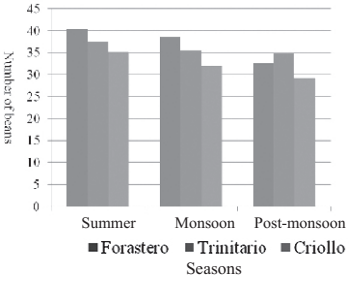

Fig. 3. Seasonal influence of number of beans during three seasons

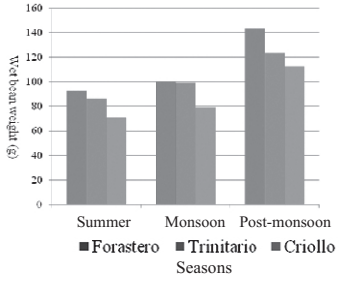

Fig. 4. Seasonal influence of wet bean weight (g) during three seasons

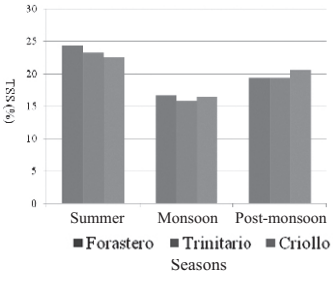

Fig. 5. Seasonal influence of TSS (%) during three seasons

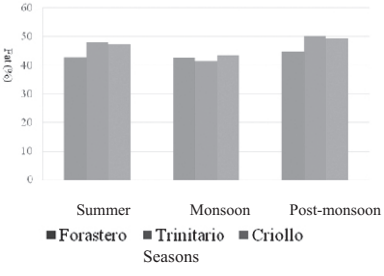

Fig. 6. Seasonal influence of fat (%) during three seasons

The correlation of weather parameters with important characters are shown in Tables 2 to 5. The data showed that number of rainy days, rainfall and relative humidity were having a negative correlation with number of pods (Table 2). The outcome is upheld by the actual recorded data on number of pods. Gomes *et al*. (1987) revealed that stomatal opening is increased when relative humidity is more resulting in high vegetative growth. Increased vegetative growth and increased flower production never harmonize in cocoa. This is because stored food is almost nil in this tree (Wood and Lass, 1985) and high vegetative growth results in low flower formation, flower drop, and cherelle wilt. Periodic and concentrated pruning of less effective shoots can reduce this impact to certain extent. Mean sunshine hours have a positive correlation with pod weight, wet bean weight and TSS (Tables 3,4 and 5). This is reflected in the data during post-monsoon period. TSS was also influenced positively by temperature and adversely by rainfall.

Table 2. Correlation of weather parameters with yield (number of pods tree^{-1})

Cocoa types	Max. Temperature (^{o}C)	Min. Temperature (^{o}C)	RH morning (%)	RH evening (%)	Rain fall (mm)	Rainy days	Mean sunshine hours
Forastero	.395*	-.466**	-.568**	-.541**	-.480**	-.458**	.524**
Trinitario	-.377*	-.553**	-.489**	-.486**	-.483**	-.486**	.475**
Criollo	.357*	-.546**	-.752**	-.645**	-.685**	-.585**	.645**

* Significance at 5% ** Significance at 1%

Table 3. Correlation of weather parameters with pod weight (g)

Cocoa types	Max. Temperature (^{o}C)	Min. Temperature (^{o}C)	RH morning (%)	RH evening (%)	Rain fall (mm)	Rainy days	Mean sunshine hours
Forastero	.395*	-.466**	-.568**	-.541**	-.480**	-.458**	.524**
Trinitario	-.377*	-.553**	-.489**	-.486**	-.483**	-.486**	.475**
Criollo	.357*	-.546**	-.752**	-.645**	-.685**	-.585**	.645**

* Significance at 5% ** Significance at 1%

Table 4. Correlation of weather parameters with wet bean weight

Cocoa types	Max. Temperature (^{o}C)	Min. Temperature (^{o}C)	RH morning (%)	RH evening (%)	Rain fall (mm)	Rainy days	Mean sunshine hours
Forastero	- .358*	- .697**	- .110	.064	.041	.085	.018
Trinitario	.176	- .354*	- .637**	- .457**	- .475**	- .452**	.453**
Criollo	.126	- .363*	- .625**	- .449**	- .534**	- .450**	.480**

* Significance at 5% ** Significance at 1%

Table 5. Correlation of weather parameters with TSS

Cocoa types	Max. Temperature (°C)	Min. Temperature (°C)	RH morning (%)	RH evening (%)	Rain fall (mm)	Rainy days	Mean sunshine hours
Forastero	.460**	.103	-.715**	-.645**	-.623**	-.617**	.726**
Trinitario	.282	.053	-.354*	-.364*	-.381**	-.382**	.313*
Criollo	.783**	.399**	-.694**	-.748**	-.668**	-.731**	.709**

* Significance at 5% ** Significance at 1%

Table 6. Canonical correlation of Criollo, Trinitario, Forastero

Clones	Characters combined	Pod weight (g)	Pod length (cm)	Pod breadth (cm)	Husk thickness (cm)	No. of beans	No. of flat beans	Wet bean weight (g)	TSS (%)
Forastero	.98506	.78225	.89943	.90579	.89031	.62836	.72011	.82358	.95986
Trinitario	.96556	.80629	.66387	.85077	.93737	.54152	.66747	.82967	.67213
Criollo	.97810	.93351	.85929	.80111	.87446	.72587	.83231	.94275	.95076

In order to comprehend the significance of selected weather parameters on pod characters and the TSS canonical correlation was estimated (Table 6). The results showed a high value for all the weather parameters selected indicating high influence of these parameters on all characters observed.

The result on regression models for prediction of economic characters like the number of pods per tree, wet bean weight and dry bean weight are presented in Tables 7, 8 and 9 respectively. High R^2 value indicated the reliability of the prediction model and pointed out the scope of this method for prediction of the above characters. Rainfall, temperature and relative humidity were the three main climatic factors influencing the yield parameters. Rainfall and sunshine hours were the two important components for Forestero while temperature played a key role in the performance of Criollo and Trinitario. Lawal and Emaku (2007) studied influence of these parameters on cocoa yield in Ghana and also reported that they contributed very much to yield. In the regression study conducted by Lawal and Omonona (2014) in cocoa, yield against rainfall expressed negative relationships, whereas temperature and relative humidity exhibited positive relations.

Table 7. Prediction for pod weight

Cocoa types	Regression models	R^2
Forastero	5.020 + -19.346 * Sunshine hours (10^{th} week) + 4.4871 * RH_1 (1^{st} week)	0.65
Trinitario	-9.14.463 +72.844*Min. Temp. (4^{th} week) + 192.268 * Rainy days (17^{th} week) + -5.001 * RH_1 (14^{th} week)	0.72
Criollo	2566.924 + -65.357 * Max. Temp. (14^{th} week) + -4.925 * Rain fall (14^{th} week) + -14.929 * Sunshine hours (8^{th} week)	0.95

Table 8. Prediction for wet bean weight per pod

Cocoa types	Formulas- regression models	R^2
Forastero	15.9111 + .844 * RH_2 (10^{th} week) + 1.029 * Rain fall (15^{th} week) + -.618 * rainfall (14^{th}week)	0.79
Trinitario	88.959 + 17.651 * Min.Temp. (4^{th} week) + -9.172 * Max. Temp. (10^{th} week) + -1.834 * RH_2 (9^{th} week) + 1.062 *RH_1 (11^{th} week)	0.94
Criollo	5.8.897 + 13.236 * Max. Temp. (15^{th}week)	0.77

Table 9. Prediction for dry bean weight per pod

Cocoa types	Formulas- regression models	R^2
Forastero	413.930 + -44.007 * Min.Temp. (6^{th} week) + -3.706 * RH_1 (1^{st} week)	0.48
Trinitario	1179.574 + -27.166 * Max. Temp. (12^{th} week) + 4.516 * max. Temp. (9^{th} week)	0.51
Criollo	72.834 + -6.331 * RH_1 (6^{th} week) + 8.094 * RH_1 (9^{th} week) + -2.7666 * RH_2 (11^{th} week)	0.68

Additional care throughout summer for water conservation by mulching, husk burial, *etc*. will facilitate to diminish the adverse after effects experienced during rainy season. Irrigation throughout summer is suggested to tackle the problem of low yield during monsoon harvest.

References

Aikpokpodion, P.O. 2012. Defining Genetic Diversity in the Chocolate Tree, *Theobroma cacao* L. Grown in West and Central Africa. In: *Genetic Diversity in Plants*. (Ed.) Prof. Mahmut, C. Available from:http://www.intechopen.com/books/genetic-diversity-in-plants/defining-geneticdiversity-in-the-chocolate-tree-theobroma-cacaogrown-in-west-and-central-africa. pp. 185-212.

Ajmal, P.M. 2016. Evaluation of selected cocoa (*Theobroma cacao* L.) hybrids bred for quality. MSc Thesis, KAU, Vellanikkara, Kerala, India, 128p.

Almeida, A.F. and Valle, R.R. 2007. Ecophysiology of the cacao tree. *Brazilian Journal of Plant Physiology* **19**(4): 425- 448.

Cheeseman, E. 1944. Notes on the nomenclature classification and possible relationships of cocoa populations. *Tropical Agriculture* **21**: 145-146.

Efombagn, M.I.B., Sounigo, O., Nyassé, S., Manzanares-Dauleux, M. and Eskes, A.B. 2009. Phenotypic variation of cacao (*Theobroma cacao* L.) on farms and in the gene bank in Cameroon. *Journal of Plant Breeding and Crop Science* **1**(6): 258-264.

Egbe, N.E. and Owolabi, C.A.1972. Quality of Nigerian commercial cocoa beans. *Turrialba* **22**(2):150-155.

Gomes, A.R.S., Kozlowski, T.T. and Reich P.B. 1987. Some physiological responses of *Theobroma cacao* var. catongo seedlings to air humidity. *New Phytologist* **107**: 591-602.

Lawal, J. O. and Emaku, L. A. 2007. Evaluation of the effect of climatic changes on cocoa production in Nigeria: Cocoa Research Institute of Nigeria (CRIN) as a case study. Available from: https://www.researchgate.net/publication/228757198. [accessed Aug 06 2018].

Lawal, J.O. and Omonona, B.T. 2014. The effects of rainfall and other weather parameters on cocoa production in Nigeria. *Comunicata Scientiae* **5**(4): 518-523.

Manikandan,N. 2009. Crop weather relationships of cocoa (*Theobroma cacao* L.). *M.Sc Thesis*, KAU,Vellanikkara, Kerala, India. pp. 81.

Minimol, J.S., Shija, T.K., Nanthitha, V., Sunil, K.M., Suma, B. and Krishnan, S. 2015. Seasonality in cocoa: Weather influence on pod characters of cocoa clones. *International Journal of Plant Sci*ences **10**(2):102-107.

Prameela, K.P. 1997. Effect of weather on cocoa and improvement of bean size through seasonal orientation. *M.Sc Thesis*, KAU, Vellanikkara, Kerala, India. pp.119.

Prasannakumari Amma, S., Mallika, V.K., Lalitha Bai, E.K. and Minimol, J.S. 2018. Cocoa. In: *Biodiversity in Horticultural Crops*. (Ed.) Peter, K. V, New Delhi. pp.267-295.

Prasannakumari Amma, S., Mallika, V.K., Rao, P.G.S. L.H.V. and Sudeesh, M.V. 2005. Crop weather relationships of cocoa. In: *Proceedings of the National Workshop on Drought Management in Plantation Crops*, (Eds.) Nybe, E.V. and Rao, P.G.S.L.H.V. Kerala Agricultural University, India. pp. 53-57.

Prasannakumari Amma, S., Nair, V.R., Lalitha Bai, E.K., Mallika, V.K., Minimol J.S. Abraham, K. and Savithri, K.E. 2009. *Cocoa in India*. Kerala Agricultural University, India. 72 pp.

Rubeena, M. 2015. Analysis of bean characters in cocoa (*Theobroma cacao* L.) hybrids bred for bold beans. MSc Thesis, KAU, Vellanikkara, Kerala, India. pp. 67.

Trognitz, B., Scheldeman, X., Hansel-Hohl, K., Kuant, A., Grebe, H. and Hermann, M. 2011. Genetic population structure of cacao plantings within a young production area in Nicaragua. *Plos One* **6**(1): 1-13.

Wood, G.A.R. and Lass, R.A. 1985. *Cocoa*. Tropical Agriculture Series, Longman Publications, New York. 620 p.

Yang, J.Y., Scascitelli, M., Lambert, A.M, Sveinson, S., Engels, J.M.M., Kane, N.C., Dempewolf, H., Zhang, D., Maharaj, K. and Cronk, Q.C.B. 2013. Complex origin of Trinitario type *Theobroma cacao* (Malvaceae) from Trinidad and Tobago revealed using plastid genomics. *Tree Genetics and Genomes* **9**(3): 829-840.