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Fruiting Patterns of Cacao as Affected by Shading Regimes

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Abstract

Effects of different shading regimes (dense, moderate, and no shade) on the fruiting pattern of 2-3 years old cacao was investigated at the Teaching and Research Farm of the Federal University of Technology Akure, Nigeria between October 2014 to April 2015 which marks the first production season of the cacao plants. Plantain shade and no shade treatments that have been imposed on the cacao from establishment were studied to determine its effect on the fruiting pattern and yield. The treatments were dense shade, moderate shade and no shade which were arranged in a completely randomized design. No shade treatments significantly influenced pod production compared to dense and moderate shade at every period of data collection. More so, no significant difference was observed in the number of pods produced between moderately shaded plots and the densely shaded plots. No significant difference was observed among the treatments in weight of one pod, but the total pod weight was significantly higher under no shade compared with dense and moderately shaded plots. A number of beans per pod were not different significantly among the three-shade treatments. However fresh weight of bean per pod was significantly higher under no shade over other shade treatment. The total bean weight per treatment was significantly higher in no shade treatment compared to dense and moderately shaded plots. It was generally observed that pod production pattern in 2-3-year-old cacao production was positively influenced under no shade compared with dense and moderately shaded cacao.

Keywords

cacao, Variability of Cacao, Relative Humidity of Cacao, Effect of Rainfall on Cacao Production, Fruiting Patterns of cacao

1.0 Introduction

Cacao is a tropical green tree which was originated from American and later adopted and now been cultivated by most West Africans countries(Heiser, 2016). Cacao has been identified as a valuable cash crop in Nigeria, it looks like a bean in form of seeds in which likes of cocoa and cocoa butter were extracted. It is grown mainly by about 80% of the small-scale farmers of west African region. Cacao has contributed immensely in boosting economic growth of Nigeria and has facilitated a substantial increase in the employment rate of the country(Lasisi, Olayinka, 2017).

Cacao which is the main producer of cocoa is of great economic importance to foreign exchange earnings, production of beverages and chocolate, cocoa juice, cream, organic nutrient sources, employment generation, ornamental, among others has drastically enhanced income generation and has a positive impact on Nigeria economy(Uzochukwu, 2017, Zhang, Motilal, 2016, Adejobi, Agele & Aiyelari, 2017, Fawole, Ozkan, 2018, Ogunjimi, Alao & Alabi, 2017, Arowolo et al., 2016, Noble, 2017).

Cocoa which is a product of cacao was primarily consumed by the people of mo kaya, an ethnic group in the southern part of Mexico. Spaniards were the ones who introduced cocoa consumption to the European community, during this period, it was mainly consumed by the royal families owing to its cost before it later became a popular beverage in

Europe in the mid-seventeenth century(Steve T. Beckett (Editor), Mark S. Fowler (Editor), Gregory R. Ziegler (Editor), May 2017).

The deleterious effects of drying and strong winds like harmattan in West Africa are reduced through windbreaks, shade trees or even by high-density planting. This is because cacao rooting is superficial thus offering little resistance to strong and drying winds. The climatic features that disturb cacao planting include relative humidity as well as rainfall and temperature, all these factors disturb cocoa yields and export in Nigeria. The climatic change has a greater effect on cocoa production, some uncomplimentary climatic circumstances will bring about negative effects on cocoa which will lead to low exports of products extracted from cacao, if the farmland experiences drought, disproportionate temperature, truncated rainfall, this will equally reduce production activities leading to a huge regression in export activities on cacao products(Aigbekaen, Agbongiarhouyi & Adejumo, 2009). High relative humidity will bring about increased evapotranspiration on the plant which will eventually lead to low production and development especially in flowering and pod formation. Excessive rainfall brings about disease incidence (black and brown pod) and leads to flower abortion/drops and cherelles wilt and delay in drying the cocoa beans.

Cacao cultivation is usually done in a secluded insipid forest that has a good shade(Lobão et al., 2007). Its cultivation in such environment is to compliment a sustainable attribution of a natural assorted forest, which has proven to be one of the suitable effective plant communal for the shield of humid soil to protect from degradation mediators. Cacao has been found to survive with other crops via intercropping planned system which has been practiced everywhere in the world. Crops species of great economic values, such as *Cocos nucifera, Hevea brasiliensis, Erythrina fusca* and other Amazonian species in planned association. Though, cocoa is found to be cropped in unshaded environments as well. Shade protects cacao seedlings in their vulnerable stage of growth in the nursery from the intense sun, wind and heavy rainfall. It reduces excessive sunlight incident which prevents vegetative growth (flushing) and leaf development. This study seeks to evaluate the effect of shade on cacao fruiting patterns of cacao of 2-3 year of cultivation and also, to establish the effect of shade on pod size as well as the quantity of seed in relation to pod, total number of cocoa beans produced by a 2-3-year-old cacao

2.0 Literature Review

2.1. Ecology of cacao

Cacao has been found suitable for acclimatizing with twelve-monthly rainfall of 4.8 to 42.9dm, a yearly temperature between 18.0ºC to 28.5^0C, a P^h value of 4.3 and 8.7. it has been established that trees are used in controlling winds, therefore many people often plant trees on hillsides to guide against winds attacks. Trees are often planted around cacao cultivation to safe guide it from winds attacks. Cacao having found to be drought biased, cacao flourishes well in an environment when it's climatic conditions are well-favored with substantial rainfall and high humidity(Oyekale, 2012, Adeniyi, Ogunsola, 2014). Cacao flourishes well under shade where the farmland is engrossed with well-drained soil, fertile soil, soils which are moist and deep in nature are also found palatable. Shallow soils are found not suitable for cacao cultivation. Cacao plantation can still survive with a temperature of 33.5ºC, which is the maximum which cacao crop can tolerate and minimum temperature of 13^oC.

In most West Africa, cacao plantations are gradually invading on valuable rain forest environments as well as humid dry forest zones, which causes erosion and, leads to irreversible deficiencies in the ecosystem as well as biodiversity. During the dry season, the occurrence of harmattan winds brings an air of very low relative humidity may cause serious defoliation of cacao trees. Otherwise, relative humidity and an overcast sky may serve to ameliorate adverse effects of long periods of very low rainfall this tends to explain the success of cacao in some parts of the middle belt of West Africa. However, there is a limit to this amelioration effect as casual observation has shown that cacao cultivation is uneconomic in the low humidity – low rainfall northern areas of the cacao growing countries of West Africa. When the soil moisture is adequate, high air humidity is undesirable for cacao, as this favors the spread of some of deadly diseases. In most parts of West Africa, the dry harmattan winds are prevalent from December to February.
In Nigeria, a wide range of cacao are cultivated in the Southern part of the country, in the rain forest zone where the temperature and the rainfall are adequately supplied throughout the year. It is observed that Cocoa farming in Southern

part of Cameroon, as well as the Southwestern part of Nigeria varied than the cacao cultivation, approaches adopted in the main producer nations such as Ghana as well Cote d'Ivoire.

2.2 The climatic requirement of cacao

Cocoa is known to be reactive to changes in climatic features such as hours at which the sunset out, slight alteration in the rainfall, inappropriacy in the wetting of soil as a supplement for rainfall, even change in temperature could affect cacao due to its impacts on evapotranspiration. This change in the climatic features could disrupt the rates of growth of cacao pests as well as pathogens, it could change the host resistance, which in turn leads to variations in the composition of pest's interaction(Anim-Kwapong, Frimpong, 2005).

Usually, Modification in the topographical distribution of host, as well as pests, is considered as one of the effects of these changes. The altered crops profits, its loss, this are what determines the socioeconomic features, such as the farm income and this determines the decision-making process in the farm(Anim-Kwapong, Frimpong, 2005). The impulses in the climatic and weather condition in recent years has a significant effect on cocoa production, which is an extraction from cacao and it forms the main cash crop. Disparities in both rainfall and temperature have always been a barrier which often affects the germination and growing of the cacao tree, as well as the production of cocoa pods. The variability in temperature and rainfall has led to variations in cocoa yield and output.

2.2.1. Effects of Rainfall, Temperature and Relative Humidity on flowering of cacao

An investigation was carried out at a Cocoa Research Institute, in the southwestern part of Nigeria, Ibadan in Oyo State by Omolaja in (Omolaja et al., 2009) to survey the effect of temperature as well as rainfall on some selected breed of Amazon Cocoa (*Theobroma cacao*), this was done to deduce its flowering intensity and, its pollen fertility. In his study, he observed that the selected Theobroma cacao produced its highest number of flowers in the month of May. There is a report that flowering that substantiated its fact that flowering intensity in cacao is usually at its peak I between April and June, which agrees with the survey done by omolaja. Increment in the rainfall between April and May has a significant effect on the flowering intensity of cacao than in January where the rainfall is not as intensive as during April and May. A warm climatic environment, an intense rainfall enhances flushing as well as flower initiation in Theobroma cacao. Mohr *et al* in his study, observed the sequence of flower initiation, its shape, and morphogenesis, even though its attributes are dependent on the environment features which is controlled endogenously and differs among other cultivars. In Nigeria, it is observed that high rainfall, as well as satisfactory temperature, supports flowering intensity in cacao. Also, Obatolu *et. al.*, enumerated in his study that there are some factors which consistently affects the growth of cacao plant, these factors are said to be mainly weather fundamentals such as rainfall, humidity, temperature, sunlight and, some other factors such as status of the soil nutrients, among others are pests farming practices as well as diseases.

An average rainfall ranging between 1250mm to 3000mm on yearly basis is said to be the most suitable rain pours which will enhance the flowering intensity of cacao tree to adequately flourish. Though, it is most preferable to have 1500mm to 2000mm rainfall during the dry season, with 1000mm rainfall per month which is the ideal quantity, even though it's not as important as its distribution. During the dry season, rainfall can be augmented with irrigation system. Excessive rainfall makes the flowers to fall off and can encourage cherelles wilt. Inadequate rainfall can cause dehydration of the cacao trees and reduces the cocoa production out rightly. Cacao is allergic to water shortage mostly when in rivalry with other plants such as windbreaks planted to protects it from wind attacks as well as weeds, it is also sensitive to surplus water in the soil(Obatolu, C.R.: Fashina AB, Olaiya AO, 2003). Transpiration and evaporation of soil water are rapid when the temperature is relatively high.

Temperature fluctuating amid 30-32^{O}C which is at its maximum, temperature between 18-21^{O}c at its minimum. But when the temperature is around 25^{O}C, it is considered as a favorable temperature state. High temperature brings about transpiration, most cacao tree will drop their leaves and it will reduce the growth of cacao and the fruiting pattern of the tree. At a temperature lower than 10^{O}c, cacao becomes damaged.

The relative humidity is consistently high in cacao cultivating areas, at night, it is frequently at 100% dwindling to about 80% or less during the day, occasionally in the dry season. Cacao enjoys high relative humidity of between 70 -

80% above which disease infection occurs and below which is obtainable in the dry season. Cacao leaves become limp and droop, thus causing severe defoliation.

2.3 Effects of Shade density and cacao growth and development

The act of using shade trees is a well-known tradition in the cultivation of cacao. The temporary shade is beneficial during the early years before the cacao canopy closes. The ideal nurse shade for cacao should be easy to establish and provide within a short time, a good overhead shade throughout the dry season. The cacao tree desires shield from straight sun as well as wind, which necessitated the need for a cover of shade to flourish. Cacao seedlings are frequently cultivated under the shelter of higher grown trees or crops like plantain, coconut, banana, etc. This tends to offer the essential shade and at the same time producing other prominent yields. Cacao tree grew in the shade provided by food and cash crop. Cacao seedling is fragile and therefore it needs to be protected from straight sun and wind, hence, the need for shade is inevitable. Once the cacao trees are established, they can tolerate much more sunlight(David, 2005).

Shade covers in the plantation of cacao have a very significant impact on the growing process and productivity of the cacao tree. The shade, however, requires handful control by pruning and thinning the cacao tree, to attain the anticipated level of shade and exploit growth as well as production. The shade has a very complex effect on cacao tree. The shade has an influence on microclimate of the cacao block via its consequence on the quantity of solar pollution grasped by the cacao trees, its wind, and its relative humidity as well as via its impact on the metabolic proportion of the cacao trees and its productivity, which ramblingly impacts the nutrient condition of the soil. The said micro-climate invariably impacts the occurrence of pests and diseases(I.C.C.O.: 2003). In Ecuador, half of the new coca is substituting shade plantation in coca-cultivation districts. For example, in Ecuador, half of the newly cultivated cacao is being subjected to full-sun, with high resilient variety(Bentley, Boa & Stonehouse, 2004). In (R.A, 2008) report on farmers retaining and planting trees with different quality of shade as a practice to reduce temperature, wind speed, evaporation, and direct sunlight exposure as well as to intercept rain thus, influencing the local microclimate. A recent study by (Waldron et al., 2012) explored the trade-offs between biodiversity conservation and production shade reduces yield in cocoa farms in Ecuador. Removing shade from cacao has resulted in significant increases in yield with a positive interaction between increased light and applied nutrients(1. F., R., O., D., L., A.A., D, S, (2006)).

Shade brings about a decrease in diurnal differences in soil as well as air temperature, brings about decrease in wind passage and enhances improved mineral recycling. Shade covers formed by other plants is a necessity for young cacao plants to restore the physiological strain triggered by high light concentrations and helps to condense evapotranspiration. Ruf's research in Ghana where farmers using hybrids believe that shade and agroforests may even provide negative ecological services, such as increased damage by pest and diseases like the black pod.

3 Materials and Method

An existing 2-3 years old cacao plantation established in June 2012 in the Teaching and Research Farm of FUTA was used for the experiment. The cacao plantation was established in June 2012 under three shade regimes: Dense shade (one cacao row: two plantain rows) moderate (one cacao row: one plantain rows) and no shade (open sun) and were irrigated during the first two dry seasons using a drip irrigation system. Twenty-four (24) cacao stands as a replicate. The experiment involves three treatments that were replicated three-time under a completely randomized design.

The developmental pattern in term of fruit production on the selected cacao stands was monitored for six months (October 2014 to April 2015)

Data were collected on a number of pod, a number of bean/pod and total bean weight were taken on fruiting pattern 1 during the course of the experiment.

Data Collection

At two weeks interval, fruit count was talking on the well-formed cherelles. On yield parameters, at four weeks interval, the number of riped pods were counted and harvested. The total weight of harvested pods per stand per treatment was taken and the weight of one pod. The pods were broken to extract the beans from the pod and the bean weight for one pod and total bean weight per treatment was taken with the aid of a sensitive balance. The number of beans in a pod was counted. Also, total weight of the pod was taken from a stand and the weight of the beans after extraction was taken also. The cocoa beans were fermented and sun-dried after five days to determine the bean yield per plot.
Collected data was exposed to the investigation of discrepancy using GENESTART as well as the mean detached using Turkey test.

4.0 Findings and discussions

Findings derived from the studies carried out on whether there is a significant effect of shade regime on pod production. Table 1 below shows the effects of shade regime on cacao pod production pattern observed in 12 weeks. From the result, it was observed that at 30 months after transplanting (October 2014) pod production was significantly higher under no shade compared to dense and moderately shaded cacao. More at 31months after transplanting, (November 2014) No shade had a significantly higher number of pods over the dense and moderate plots but no significant difference between moderate and dense shade cacao in pod production rate. Between 32-35 months after transplanting, no shade produced a significantly higher number of pods compared to dense and moderately shaded cacao.

Table 2 shows the effects of shade treatments on Total pod number. Total pod number was significant across the three treatments with no shade plots having the highest significant total pod number compared with the moderate and the densely shaded treatments. No significant difference in the total pod number between moderate and dense shaded plots but the value of moderate was higher than that of dense shade plots. More so, the weight of one pod was almost the same in the three-shade treatments, there was no significant difference but the weight of one pod in no shade plot was higher than moderate dense shade treatments. Total pod weight was significant across the three treatments with no shade plots having the highest significant total pod weight compared with the moderate and the densely shaded treatments. No significant difference in the total pod weight between moderate and dense shaded plots but the value of moderate was higher than that of dense shade plots.

Table 3 shows the effects of shade treatments on the number of beans per pod, fresh bean weight per pod and total bean weight per treatment. It was detected that there were no substantial modifications in the number of beans per pod. The number was higher in no shade treatment than moderate and dense shade treatments. The average number of beans per pod was forty beans. There was no significant difference in fresh bean weight per pod of coca under the three-shade regimes despite in no shade treatment fresh bean weight was higher than moderate and dense shaded. But in no shade, the total weight of bean per treatment was significantly higher compared to moderate and dense shades which were not different significantly from each other.

There are higher significant differences in the total weight of bean in no shade regime compare to dense and moderate shade regimes but no significant difference between dense and moderate shade regimes.

Table 1. Effects of shade regime on pod production

Shade treatment	Months	After	Transplanting			
Moderate Shade	30 0.33c	31 11.00b	32 6.33a	33 11.67a	34 3.00a	35 1.00a

Dense Shade	11.33b	5.33a	3.67a	9.33a	9.67a	2.33a
No Shade	17.67a	26.00a	15.67a	24.67a	13.67a	8.33a

Table 2. Effects of shade treatments on Total Pod Yield.

Shade treatment	Total pd (No)	Weight of one pod (g)	Total weight of the pod (kg)
Moderate shade	012.33b	433.33a	12.63b
Dense shade	18.00b	456.67a	9.37b
No shade	29.33a	493.33a	34.87a

Means in the same column trailed by the same letter or letters which are not meaningfully different by Turkey test P≤0.05

Table 3. Effects of shade treatments on weight of one pod and bean weight

Shade Treatment	No of bean Per pod	fresh bean Weight/pod	Total bean weight/treatment
Moderate shade	40.00a	153.33b	2.89b
Dense shade	39.00a	166.67b	3.97b
No shade	43.33a	183.33a	11.63b

Means in the same column trailed by the same letter or letters which are not meaningfully different by Turkey test P≤0.05

4.0 Conclusion and Recommendation

Cocoa should be grown under no shade condition provided there is adequate provision for irrigation during the dry season and this will improve bean yield and quality in terms of average bean weight. It was also concluded that dense shade reduces pod formation in cacao. Pruning and dry season irrigation are recommended for cacao production.

Pruning and dry season irrigation are recommended for cacao production.

References

1. F., R., O., D., L., A.A., D, S (2006), *.: Intensification in Cocoa Cropping system: Is Agroforestry a solution for sustainability? A case study of Manso Amenfi. Western Region*.

Adejobi, K.B., Agele, S.O. & Aiyelari, P.O. 2017, "EFFECTS OF ORGANIC MANURE ON SOIL PROPERTIES AND HEALTH AND GROWTH PERFORMANCE OF CACAO (Theobroma cacao L) IN SOUTHWESTERN NIGERIA", *Journal of Global Biosciences,* vol. 6, no. 4, pp. 4876-4895.

Adeniyi, O. & Ogunsola, G. 2014, "Cocoa production and related social-economic and climate factors: A case study of Ayedire local government area of Osun State, Nigeria", *Agricultural Science,* vol. 2, no. 4, pp. 1-13.

Aigbekaen, E., Agbongiarhouyi, A. & Adejumo, M. 2009, "Factors affecting yield and revenue of cocoa at the Cocoa Research Institute of Nigeria's Main Station, Onigambari.", *9th African Crop Science, Conference Proceedings, Cape Town, South Africa, 28 September-2 October 2009*African Crop Science Society, pp. 751.

Anim-Kwapong, G. & Frimpong, E. 2005, "Vulnerability of agriculture to climate change-impact of climate change on cocoa production", *Accra, Ghana,*

Arowolo, A., Shuaibu, S., Sanusi, M. & Fanimo, D. 2016, "ANALYSIS OF THE DETERMINANTS OF PROFIT FROM COCOA BEANS MARKETING IN OGUN STATE, NIGERIA", *Journal of Agricultural Science and Environment,* vol. 16, no. 1, pp. 9-19.

Bentley, J.W., Boa, E. & Stonehouse, J. 2004, "Neighbor trees: shade, intercropping, and cacao in Ecuador", *Human Ecology,* vol. 32, no. 2, pp. 241-270.

David, S. 2005, "Learning about Sustainable Cocoa Production: A Guide for Participatory Farmer Training 1. Integrated Crop and Pest Management", *Sustainable Tree Crops Program, International Institute of Tropical Agriculture, Yaounde, Cameroon,*

Fawole, W.O. & Ozkan, B. 2018, "Revisiting the profitability and technical efficiency of cocoa production amidst economic diversification program of the Nigerian Government: A case study of Ondo State", *Journal of Agribusiness in Developing and Emerging Economies,* vol. 8, no. 1, pp. 186-200.

Heiser, C.B. 2016, *The gourd book,* University of Oklahoma Press.

I.C.C.O.: 2003, *International Cocoa Organisation's Quarterly Bulletin of Cocoa statistics*.

Lasisi, J.O. & Olayinka, A.S. 2017, "Business development and economic recession in Nigeria: lessons and the way forward", *The Business & Management Review,* vol. 8, no. 4, pp. 300.

Lobão, D., Setenta, W., Lobão, E., Curvelo, K. & Valle, R. 2007, "Cacau cabruca: sistema agrossilvicultural tropical", *Ciência, tecnologia e manejo do Cacaueiro,* , pp. 290-323.

Noble, M.D. 2017, "Chocolate and The Consumption of Forests: A Cross-National Examination of Ecologically Unequal Exchange in Cocoa Exports", *Journal of World-Systems Research,* vol. 23, no. 2, pp. 236-268.

Obatolu, C.R.: Fashina AB, Olaiya AO 2003, " Effects of Climate Changes, Lagos, Nigeria", vol. 5.

Ogunjimi, S., Alao, O. & Alabi, O. 2017, "NEXUS BETWEEN INTERNAL VALUE CHAIN FINANCE AND COCOA PRODUCTION IN SOUTHWESTERN NIGERIA: IMPETUS TO AGRICULTURAL PRODUCTIVITY AND SUSTAINABILITY", *Ife Journal of Agriculture,* vol. 29, no. 1, pp. 14-23.

Omolaja, S., Aikpokpodion, P., Oyedeji, S. & Vwioko, D. 2009, "Rainfall and temperature effects on flowering and pollen productions in cocoa", *African Crop Science Journal,* vol. 17, no. 1.

Oyekale, A.S. 2012, "Impact of climate change on cocoa agriculture and technical efficiency of cocoa farmers in South-West Nigeria", *Journal of human ecology,* vol. 40, no. 2, pp. 143-148.

R.A, A.R.A. 2008, *A Participatory Approach for Tree Diversification*

Steve T. Beckett (Editor), Mark S. Fowler (Editor), Gregory R. Ziegler (Editor) May 2017, "**Beckett's Industrial Chocolate Manufacture and Use, 5th Edition** ".

Uzochukwu, I.E. 2017, *Growth, Gonadal Development, And Blood Profile In African Catfish (Clarias gariepinus, Burchell 1822) Fed Diets Containing Cocoa Bean Meal,*

Waldron, A., Justicia, R., Smith, L. & Sanchez, M. 2012, "Conservation through Chocolate: a win-win for biodiversity and farmers in Ecuador's lowland tropics", *Conservation Letters,* vol. 5, no. 3, pp. 213-221.

Zhang, D. & Motilal, L. 2016, "Origin, dispersal, and current global distribution of cacao genetic diversity" in *Cacao diseases* Springer, pp. 3-31.

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