INFLUENCE OF ENVIRONMENTAL FACTOR (RAINFALL) ON COCOA BEAN QUALITY PARAMETERS.

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ABSTRACT

Cocoa bean quality attributes are influenced by environmental factors. Therefore, in this study the influence of one of the environmental factors (rainfall) on the bean quality attributes was evaluated. The result of this study indicated a weak positive and negative correlation between rainfall and each of the bean quality parameters. The average monthly rainfall does not have a direct and significant effect on shell content, bean size, fat content and recovery rate as indicated by the weak correlation coefficient (r). Simple Pearson correlation coefficient was used to determine association between each of the beans quality attributes. There was no significant relationship between each of the bean quality attributes except between recovery rate and fat content.

Key words: *Cocoa Bean, quality attributes, environmental factors.*

INTRODUCTION

The physical quality characteristics of cocoa are bean size, fat content, shell content and recovery rate. Bean size is easily measured and it is negatively correlated with shell content. Bean size is influenced by genotype (Kuman 2005). Beans developed during the main season, normally after rainy season tended to be larger in size weighing in excess of 1g (Wood and Lass 1985). Bean size can be influenced by mineral and water availability, which is more likely to be limiting in high density planting (Lachenaud 1995). Average bean weight is determined by environment, including within and between season variations (Toxopeus and Wessel 1970), but there is no evidence of interaction between season and genotype (Lockwood and Edward 1980). Bean size is not correlated with yield (Tan 1990; Lockwood and Pang 1995).

Shells (residues of mucilage and testa) of the beans are waste. Therefore, it is preferable that shell weight be as low as possible, but of adequate thickness to protect the beans from mould and insect invasion (Wood 1975). The difference in shell can be influenced by the genotype and methods of fermentation. Fermentation method and season appears to affect shell content (Wood and Lass 1985). The shell content of the beans varies depending on genotype and is negatively correlated with bean size (Vello *et al.* 1972). Within the clones, there is no relationship between per cent testa and bean size (Eskes *et al.* 1977).

The fat content varies between genotype and is probably influenced by environmental factors. It appears that there is no genetic correlation between fat content and yield or bean size (Lockwood and Pang 1995), but there is correlation between bean size and cocoa butter within the clones (Beek *et al.* 1977). Seasonal variation is shown to affect fat content. Fat content was suggested to be influenced by bean size (Egbe and Owolabi 1972).

Recovery rate is the ratio of dry fermented beans to wet unfermented beans expressed as a percentage. Recovery rate can be influenced by season, genotype or method of processing. Pod storage prior to fermentation increased the recovery rate (Kuman 1998). Season is another major factor affecting the recovery rate (Are and Atanda 1972). The recovery rate of the genotype was significantly influenced by environmental variation (Kuman 2005).

In previous studies, suggestions were made that season, in particular rainfall, may have influenced the development of some of the important cocoa quality parameters. There were also suggestions of correlation existing between different quality parameters.

Objective

The objective of this study is to statistically verify the influence of rainfall on the bean quality parameters and the association between each of the quality parameter.

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MATERIAL AND METHODS

Location

The quality data of 31 different genotypes were collected from a breeding trial conducted at the Papua New Guinea Cocoa and Coconut Research Institute. Urguhart *et al.* (1951) provided a comprehensive description of the environmental conditions of most of the cocoa growing areas including the site for this trial. The average rainfall of 134.9 mm with a maximum of (343.9 mm) and minimum (12.5 mm) was recorded during the 24 months (from 1999-2001) of the trial.

Experimental Design

The breeding trial was divided into three sub trials based on their size. The trees of each class were of the same age uniform in each replicate and were planted in split-plot design. Four replicates were used with 12 trees in a (3 m x 3 m) plot.

Data collection

The bean content from the 31 genotypes were harvested twice every month and processed before their shell content, bean count, fat content and recovery rate were assessed. Ripe pods of approximately 1 kg (equivalent to 6 pods) were harvested twice every month from each of the 31 tested genotypes, labeled, wrapped inside the shade cloth bags and fermented using a procedure described by Clapperton *et al.* 1994. At the end of 6 days of fermentation, the test samples were dried before their shell content; bean size and fat content were assessed.

Sample collection & preparation

Approximately 600g of dried beans from each genotype was dried inside the oven (Contherm, New Zealand) at 115 ^{0}C for 15 min to standardize moisture content to less than 7p% before being emptied into a mixing container and thoroughly mixed. Any foreign material and debris was removed before passing the samples into a funnel of a quartering device, which randomly divided the samples into four quarters. Approximately 150g of beans received from each quartering devise was used to analyse the bean size (bean count), fat content and shell content (shell coat). Recovery rate is determined by weighing beans before fermentation and after drying. Weight difference is expressed as percentage.

Sample Analysis

Fat content of the beans was extracted using standard fat extraction method (AOAC, 1970). Fat

***Table 1.* Correlation between bean count, shell content, fat content and recovery**

Parameter	Bean count	Shell content	Fat content
Shell count	0.029		
	0.868		
	31	31	
Fat content	0.024	0.021	
	0.893	0.906	
	31	31	31
Recovery rate	-0.165	-0.124	0.484
	0.344	0.478	0.0043
	31	31	31

The analysis of variance to determine the influence of rainfall on bean quality parameters (Table 2-5) indicated a weak positive and negative correlations.

analysis for the hybrid clones was conducted by Cadbury Schweppes, Australia. The other quality attributes (bean size and shell content) were determined using the standard cocoa quality analysis procedure.

Data Analysis

Quality data were subjected to analysis of variance to determine the influence on bean quality by time of the year (monthly rainfall). The simple F-tests were not often possible for this analysis because of the complexity of the experimental design and the degree of imbalance due to missing of (SAS version 8, SAS Institute 1990 1996) values. F-tests with appropriate error terms were constructed by the general linear model (GLM) procedure . Simple Pearson correlation coefficient was used to determine association between each quality attributes.

RESULTS

Pearson correlation coefficient (Table 1) indicated there is no association between any of the quality parameters except between the recovery rate and the fat content.

DISCUSSION & CONCLUSION

The simple Pearson correlation coefficient (Table 1) indicated that each of the bean quality parameter is independent of each other except for a significant ($p < 0.004$) relationship between fat content and recovery rate. The recovery rate is the amount of dry yield obtained from wet beans after fermentation and drying. Fat makes up slightly more than 50% of the weight of unfermented dry beans (Lehrian *et al.* 1983), and it does not change very much during fermentation. Beans that are produced during wet season are normally large in size and have high fat content and would be expected to produce high recovery rate. However that has not always been the case as indi-

***Table* 2. Rainfall effects on shell content of the bean.**

Dependent variable: Shell content		**Regression coefficient**	Std error	t-statistic	Prob (HO):coef = 0, 2 tailed)
Monthly rainfall (mls) (Year 1999)					
January	79	**0.0001**	0.0003	0.37	0.7078
February	60	**0.0002**	0.0003	0.80	0.4254
March	344	**0.0002**	0.0003	0.59	0.5571
April	179	**-0.0006**	0.0003	-2.58	0.0100
May	108	**-0.0009**	0.0002	-3.99-	<0.001
June	113	**-0.0002**	0.0002	-7.15	<0.0001
July	76	**-0.0018**	0.0002	-7.64	<0.0001
August	12	**-0.0015**	0.0002	-6.48	<0.001
September	117	**-0.0001**	0.0002	-0.55	0.5845
October	145	**0.0002**	0.0002	0.92	0.3572
November	179	**0.0007**	0.0002	3.42	0.0006
December	188	**0.0010**	0.0002	4.78	<0.0001
January Year (2000)	79	**0.0011**	0.0002	6.61	<0.0001
February	197	**0.0013**	0.0002	6.06	<0.0001
March	201	**0.0012**	0.0002	5.58	<0.0001
April	150	**0.0011**	0.0002	4.56	<0.0001
May	103	**-0.0003**	0.0003	-1.28	0.19999
June	96	**-0.0016**	0.0003	-6.04	<0.0001
July	91	**-0.0017**	0.0003	5.58	<0.0001
August	96	**-0.0019**	0.0003	4.56	<0.0001
September	130	**-0.0006**	0.0003	-1.28	0.0281
October	152	**0.0003**	0.0002	-6.04	0.2214
November	139	**0.0040**	0.0015	-0.28	0.783
December	205	**0.0016**	0.0002	-1.05	0.293

**All rainfall figures are rounded off to the nearest whole number with an average rainfall of 134 mls.*

Table 3. **Rainfall effects on fat content of the bean.**

Dependent variable: Fat content		Regression coefficient	Std error	t-statistic	Prob (HO):coef = 0, 2 tailed)
Monthly rainfall (mls) (Year 1999)					
January	79	**-0.0001**	0.0001	-0.25	0.8008
February	60	**0.00055**	0.0004	1.20	0.2298
March	344	**0.00056**	0.0004	1.30	0.1929
April	179	**0.00131**	0.0005	2.45	0.0144
May	108	**0.00187**	0.0006	3.27	0.0011
June	113	**0.00381**	0.0010	3.62	0.0003
July	76	**0.00097**	0.0011	0.85	0.3955
August	12	**0.0005**	0.0007	0.67	0.5057
September	117	**0.0006**	0.0004	-1.53	0.1269
October	145	**-0.0006**	0.0004	-1.0	0.1329
November	179	**-0.0009**	0.0004	-2.09	0.0372
December	188	**-0.0011**	0.0005	-2.22	0.0265
JanuaryYear (2000)	79	**-0.0017**	0.0006	-3.11	0.0019
February	197	**0.0001**	0.0005	0.29	0.7740
March	201	**0.0057**	0.0004	1.28	0.2002
April	150	**0.0004**	0.0005	0.67	0.5055
May	103	**0.0010**	0.0007	1.46	0.1442
June	96	**0.0024**	0.0007	3.29	0.0011
July	91	**0.0025**	0.0008	3.06	0.0023
August	96	**0.0001**	0.0014	0.11	0.9128
September	130	**-0.0019**	0.0006	-1.47	0.1429
October	152	**-0.0003**	0.0004	-0.67	0.4928
November	139	**-0.0005**	0.0004	-1.12	0.2620
December	205	**-0.0072**	0.0004	-1.60	0.1104

** All rainfall figures are rounded off to the nearest whole number.*

Table 4. **Rainfall effects on recovery rate of the bean.**

Dependent variable: Recovery rate		**Regression coefficient**	Std error	t-statistic	Prob (HO):coef = 0, 2 tailed)
Monthly rainfall (mls) (Year 1999)					
January	79	**0.0001**	0.0008	0.12	0.9070
February	60	**-0.0017**	0.0007	-2.43	0.0153
March	344	**0.0022**	0.0006	3.30	0.0010
April	179	**0.0025**	0.0006	3.94	<0.0001
May	108	**0.0035**	0.0006	5.79	<0.0001
June	113	**0.0036**	0.0006	5.84	<0.0001
July	76	**0.0029**	0.0006	4.63	0.0543
August	12	**0.0012**	00006	1.93	0.6024
September	117	**-0.0002**	0.000	-0.53	0.0254
October	145	**-0.0013**	0.0001	-2.24	<0.0001
November	179	**-0.0022**	0.0006	-3.83	<0.0001
December	188	**-0.0035**	0.0005	-6.29	<0.0001
January Year (2000)	79	**-0.0030**	0.0005	-5.60	<0.0001
February	197	**-0.0024**	0.0005	-4.23	<0.0001
March	201	**0.0001**	0.0006	0.25	0.8044
April	150	**-0.0004**	0.0006	-0.76	0.4471
May	103	**0.0028**	0.0006	4.59	<0.0001
June	96	**0.0023**	0.0007	3.23	0.0013
July	91	**0.0032**	0.0007	4.81	<0.0001
August	96	**0.0032**	0.0007	4.78	<0.0001
September	130	**-0.0054**	0.0007	-0.70	0.4848
October	152	**-0.0008**	0.0005	-1.68	0.0931
November	139	**-0.0002**	0.0007	-0.34	0.7346
December	205	**-0.0021**	0.0006	-3.69	0.0002

** All rainfall figures are rounded off to the nearest whole number.*

***Table 5.* Rainfall effects on bean size of the bean.**

Dependent variable: Bean count		**Regression coefficient**	Std error	t-statistic	Prob (HO):coef = 0, 2 tailed)
Monthly rainfall (mls) (Year 1999)					
January	79	**-0.0028**	0.0018	-1.59	0.1128
February	60	**-0.0009**	0.0016	-0.58	0.5654
March	344	**-0.0004**	0.0015	-0.28	0.7812
April	179	**0.0005**	0.0014	0.35	0.7284
May	108	**-0.0018**	0.0013	-0.58	0.5571
June	113	**-0.0013**	0.0014	-0.95	0.3417
July	76	**-0.0026**	0.0014	-1.77	0.0761
August	12	**0.0002**	0.0017	0.14	0.8888
September	117	**0.0011**	0.0011	0.85	0.3934
October	145	**0.0017**	0.0012	1.37	0.1698
November	179	**0.0006**	0.0012	0.48	0.6323
December	188	**-0.0008**	0.0012	-0.66	0.5092
January Year (2000)	79	**-0.0001**	0.0012	-0.01	0.9954
February	197	**0.0015**	0.0012	1.18	0.2379
March	201	**0.0020**	0.0013	1.48	0.1401
April	150	**0.0006**	0.0015	0.42	0.6770
May	103	**-0.0015**	0.0014	-1.05	0.2934
June	96	**-0.0011**	0.0014	-0.68	0.4969
July	91	**-0.0018**	0.0015	-1.20	0.2294
August	96	**-0.0021**	0.0022	-0.92	0.3589
September	130	**-0.0009**	0.0018	-0.54	0.5904
October	152	**0.0023**	0.0012	1.87	0.0619
November	139	**0.0017**	0.0013	1.27	0.2058
December	205	**0.0002**	0.0013	0.17	0.8665

** All rainfall figures are rounded off to the nearest whole number.*

cated by the results of this study. The recovery rate can be influenced by the amount and structure of bean endocarp especially the pulp, which varies between different genotypes. Beans with large pulp volume to bean ratio produced during wet season would normally have a lower recovery rates than beans produced in dry seasons (Wood and Lass 1985). Recovery rate can also be influenced by genotype, pod ripeness and season. Kuman (1998) reported a variation in recovery rates between 30% to 40% for different genotypes and an increase in recovery rate for cocoa pods that are stored prior to fermentation.

There is a weak positive and negative correlation between rainfall and each of the quality parameters (Tables 2-5). The result indicated that the average monthly rainfall alone does not have a significant influence on each of the bean quality parameters; however the rainfall in combination with other environmental factors can affect the bean quality parameters. Genotype by month interactions influenced bean quality of the genotypes and this interaction contributed 12% of the total sum of squares (SS). In the analysis to study the main effects separately, monthly environmental factors contributed 3% to the total SS (Kuman 2005).

Studies of Toxopeus and Wessel (1970) indicated that there was a positive correlation between bean size and fat content and a negative correlation between bean size and shell content. The correlation between bean size and fat content is often positive and significant but there is no genetic correlation (Ekes and Lanaud 2000). In this study, no such correlation was shown to exist between any of the quality parameters except between fat content and recovery rate. The differences between the result of this study and that of Toxopeus and Wessel and Ekes and Lanaud could be explained in terms of genotypic response to genotype x environment (GXE) interactions. Different cultivars response differently to environmental variation at different stages of their growth and development and these interactions could affect the final bean quality, hence influencing the relationship between each of the quality parameters. The shell content, bean count, recovery rate and fat content contributed 8%, 12%, 12% and 28% respectively to the total sum of square (SS). The SS indicated the different responses of genotypes to environmental factors (Kuman 2005).

CONCLUSION

Rainfall alone does not have a significant influence on the development of each of the bean quality parameters, but can in combination with other environmental factors. Beans produce during wet seasons would be expected to yield high recovery rate since they are large size and contain high fat content. However this has not always been the case as the recovery rate can be influenced by genotype, season and pod storage. Recovery can be improved by pod storage prior to fermentation or through selective breeding of genotypes that only produce high recovery rate. The bean quality parameters are influenced by combinations of environmental factors including any relationship between each of the quality parameters.

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